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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

APRIL, 1937

FOOLING THE FISHES

FISHING WITH THE BATEAU AND THE WHITE VARNISHED BOARD IN CHINA AND WITH SIMILAR DEVICES IN OTHER PARTS OF THE WORLD

By Dr. E. W. GUDGER

ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

YEARS ago Bret Harte wrote the euphonious lines:

> For ways that are dark,
> And for tricks that are vain,
> The heathen Chinee is peculiar
> Which the same I am free to maintain.

It is true that, for devices ("ways," "tricks") that are curious and ingenious ("dark," "peculiar"), the Chinese perhaps excel all other peoples, not excepting Yankee inventors from the "Wooden Nutmeg State." This, westerners have known, since the return from Cathay of Marco Polo (in China and the Orient, 1275–1292) and of Friar Odoric of Pordenone (in China somewhere between 1323 and 1328). Some of the things which we believe new in our day were reported by Marco as old in the China of his day. These things are recorded in the book of Il Milione (so was our old traveler nicknamed in his native city of Venice) and are set out with a wealth of fascinating explanatory notes by Sir Henry Yule in the third edition of his "Marco Polo," edited after his death by the eminent Sinologist, Henri Cordier. Some of these things I have pointed out in an article, "Marco Polo and Some Modern Things Old in the Asia of His Day," in THE SCIENTIFIC MONTHLY for December, 1933.

The Chinese are a fish-eating people, and they have invented more ingenious engines and devices for taking fishes than have any other people known to me. Fortunately these have been figured *in extenso* and described by Pierre Dabry de Thiersant in his quarto volume "La Pisciculture et la Pêche en Chine" (Paris, 1872).

In 35 plates drawn by native Chinese artists, our author shows 120 various devices for taking fishes. These range from a simple hook and line or a trident to the most complicated fisheries engines known to the writer. One of these devices is the ingenious apparatus which is the subject of this article. It will be figured and described in its chronological order.

Neither Marco Polo nor Friar Odoric describes this method of fishing and, since Odoric does describe both fishing with the cormorant and with the otter, it seems probable that this curious device of the varnished board came into use much later than the thirteenth century.

USE OF THE VARNISHED BOARD IN CHINA

When this engine was first used, I can not say. Many of the travelers of the sixteenth century into China recorded

the use of the cormorant as a fishing agent, as I have made known in a previous article (*American Naturalist,* January–February, 1926). I have carefully gone through the works of these early voyagers, but find in none of them any reference to the use of the device under consideration.

The earliest description, which I have been able to find of fishing with the bateau and the varnished board, is from the pen of the Jesuit priest, Louis Le Compte, who went to China with other missionaries in 1685. He speaks of two methods of fishing (the second with the cormorant), and without giving any locality says:[1]

The first is practised in the Night, when it is Moonshine; they have two very long, strait Boats, upon the sides of which they Nail from one end to the other, a Board about two foot broad, upon which they have rub'd white Varnish, very smooth and shining; this Plank is inclined outward, and almost toucheth the Surface of the Water: That it may serve their turn, it is requisite to turn it towards the Moon-shine, to the end that the Reflexion of the Moon may increase its brightness, [and] the Fish playing and sporting, and mistaking the Colour of the Plank for that of the Water, jerk out that way, and tumble before they are aware, either upon the Plank, or into the Boat, so that the Fisherman, almost without taking any pains, hath in a little time his small Bark quite full.

The next describer known to me is another Jesuit missionary to China, Jean Baptiste Du Halde,[2] who speaks of a "very simple manner of taking fish and one that gives no trouble." Then he describes this curious method of fishing in terms almost identical with Le Compte's and concludes thus: "The fishes playing about easily mistake the color of the varnished board [under the moonlight] for that of the water and throwing themselves on the side of it fall on it and thence into the boat." Though Du Halde gives no details of this fishing, he does more, for he publishes the first figure, found in this study, representing this matter pictorially. In Fig. 1 are shown six boats, each with a japanned board on each side. The fishes are leaping around each boat and are falling into five of them. Two fishermen, instead of being in the boats, are seated on a parapet in the foreground, and one has thrown up a hand in apparent amazement at the scene before him.

From this time on a legion of travelers in China recount the story of this interesting fishing method, but, unless the writers add curious details or publish figures, their accounts will be passed over since their inclusion would add nothing new. Such details, however, are given in the account next to be quoted.

Not all nights are moonlight nights, even in China, and the catching of fishes must go on, and here is how it was done long ago with the boat and board on dark nights in the then Celestial Empire. In 1771 there was published at London an English version of Pehr (Peter) Osbeck's "Voyage to China and the East Indies" (originally issued in his native Swedish in 1757). On page 316 of this there begins "A Short Account of Chinese Husbandry," by Charles Gustavus Eckeberg, captain of Osbeck's ship. In this Captain Charles Gustavus describes "sampanes with white coloured boards on the sides; and in these sampanes they keep a little fire at night, which makes the fish, which pursue the fire, hop into the sampane." And thus are outwitted a "species of [jumping] fish called mullets, which leap in the dark towards the light of a fire." And ingeniously well conceived is this method of luring mullets, which are everywhere known as broad and high jumpers. Unfortunately no figure accompanies this account.

Next, Sir George Staunton in his "Au-

[1] "Memoirs and Observations . . . Made in a Late Journey through the Empire of China," p. 236. London, 1697. Translated from the original Paris edition, 1696.

[2] J. B. Du Halde, "Description . . . de la Chine," p. 142, fig. to face p. 162. La Haye, 1735. Eng. ed., London, 1738.

After Du Halde, 1735

FIG. 1. FISHING WITH THE BATEAU AND VARNISHED BOARD.

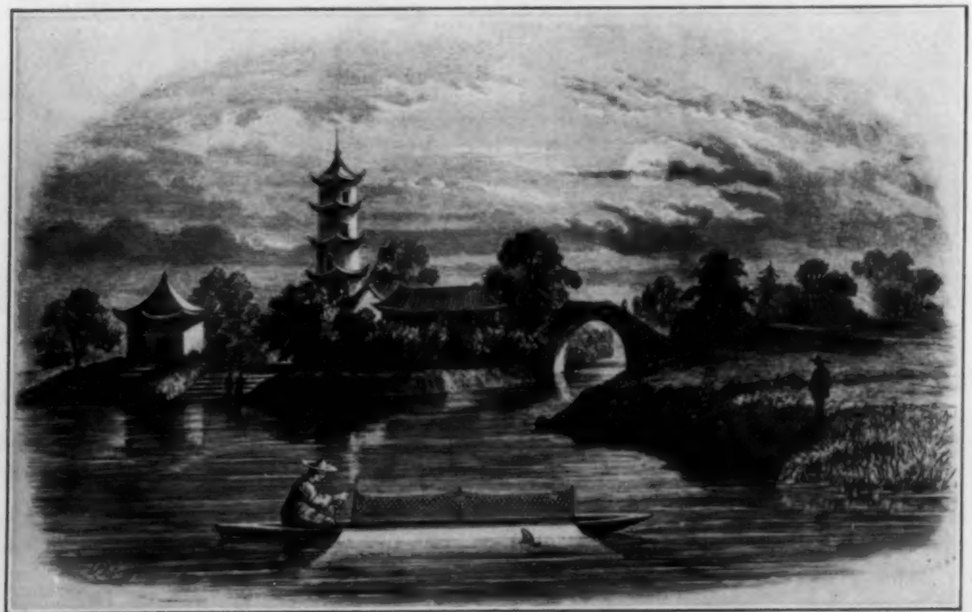
THIS IS THE EARLIEST FIGURE, SO FAR AS KNOWN, SHOWING THIS METHOD OF FISHING. NOTE A BOARD ON EACH SIDE OF EACH BOAT.

thentic Account of an Embassy . . . to the Emperor of China" (London, 1797; p. 398) adds an interesting detail. He describes boat and board and tells us that, "The fish being tempted to leap as on their elements, the boatmen, raising with strings the board, turn the fish into the boat." Unfortunately he likewise gives no figure. Later we shall see such a figure of such a device used in a far distant country.

Further details from an eyewitness are now to be given. Robert Fortune, in his book, "A Residence among the Chinese" (London, 1857, p. 375, fig.), not only gives interesting details of the construction of this curious engine of the fishery, but, unlike the other authors quoted, tells us how he *saw* it work and gives an interesting figure showing an additional device the need for which has probably occurred to some of my readers. Here is what he saw:

> The boats . . . were long and narrow. Each had a broad strip of white canvas stretched along the right side and dipping toward the water. . . . On the other side of the boat a net, corresponding in size with the white cloth, was stretched along above the bulwarks. A man sat in the stern of each boat and brought his weight to bear on the starboard side, which had the effect of pressing the white canvas into the water and raising the net on the opposite side. . . . This will be understood by a glance at the accompanying sketch [Fig. 2]. . . . It was a fine clear night and I could see distinctly the white canvas shining through the water, although several inches beneath its surface. . . . We had not remained motionless above a minute . . . when I heard a splash in the water and distinctly saw a fish jump over the boat and get caught by the net on the opposite side. The object in constructing the boats in the manner described was now apparent. It seemed that the white canvas, which dipped like a painted board into the water, had the effects of attracting and decoying the fish in some peculiar manner, and caused them to leap over it. But as the boats were long and narrow, it was necessary to have a net stretched on the opposite side to prevent the fish from leaping over them altogether and escaping again into the stream. Each fish, as it took the fatal leap, generally struck against the net and fell backward into the boat.

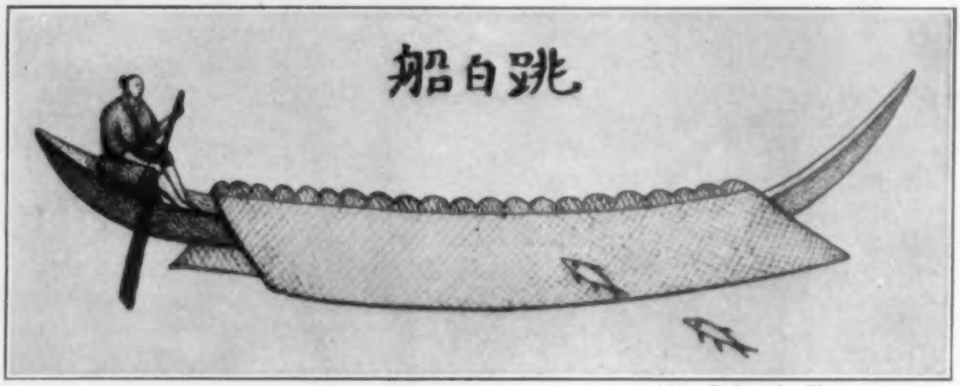
This is an excellent description by a keen eyewitness, but why did Fortune let



After Fortune, 1857

FIG. 2. BOAT WITH WHITE CANVAS AND WITH NET.

THIS IS THE EARLIEST FIGURE FOUND SHOWING A NET TO KEEP THE FISHES FROM LEAPING CLEAR OVER THE BOAT.



After Dabry de Thiersant, 1872

FIG. 3. "PÊCHE AU BATEAU BLANC, TIAO-PÉ-TCHUEN," IN CHINA.

his artist draw the boat (Fig. 2) with the canvas on the side *away* from the moon? And why is this portrayed low in the heavens? Instances of "artistic license," I presume!

The next account adds nothing new, but it is quoted because the author (Le Marquis de Courcy[3]) in true Gallic and gallant style charmingly describes the fishing:

> At night when the lucent moon throws its silvery rays on the uncertain ripples, the clever Chinese dispose along the sides of their boats long planks very flexible and painted white, since that is the color most perfectly conforming to that of the waves. Deceived by this perfidious appearance and thinking to play on the surface of the lake, the fish leaps onto the plank and slips into the boat.

And now we are come at last to the writer (Dabry de Thiersant) whose book[4] led to the collecting and setting out of the interesting accounts quoted in this article. He was for many years French consul in China, and he writes authoritatively of the ingenious device which he calls "Pêche au bateau blanc, *Tiao-pé-tchuen.*"

> When, during clear nights in the months of August, September, October, the stars sparkle in the firmament, and when the brilliant moon shines with its lovely light on the calm and limpid waters of the lakes, one perceives, gliding on their surfaces long and very narrow bateaux, nearly level with the water below, and in which at the rear is a man, leaning on his oar, guarding his manoeuvres in dead silence. This man is a fisherman, who has nailed to one of the sides of his bateaux, from end to end at an inclination of 45°, a plank glazed with a shining white varnish and whose upper extremity projects beyond the gunwale some three or four inches. On the opposite side of the bateaux there is set up a net of fine mesh. The fishes, deceived by the mirage, seek to go beyond the plank, which offers itself as a natural obstacle, and fall into the boat. Or, if their *élan* should be too impetuous, they strike against the net, which throws them down into the bottom of the boat. Many fishes are made the victims of this mirage, principally the *pe-yu* (*Leuciscus*), *houang-yu* (*Adelopeltis angusticeps*), and *ly-yu* (*Cyprinus obesus*). This ingenious device permits the taking of fish weighing as much as two and a half pounds, and is employed with the most advantage in waters which are five or six feet deep.

De Thiersant's native draftsman has made a very artistic picture (Fig. 3), but it hardly agrees with our author's text. Fig. 3 portrays a boat shaped like the crescent moon, quite unlike the others figured herein. The "board," here looking like a woven mat, seems to extend to the left gunwale of the boat, where the little scallop-edged fence is shown, and where the other board is attached. Since

[3] "L'Empire du Milieu [Chine]," p. 463. Paris, 1867.

[4] "La Pisciculture et la Pêche en Chine," Paris, 1872, p. 169, Fig. 3, pl. XXIX.

After Gray, 1878

FIG. 4. A FISHING SCENE WITH BOARD AND BOAT IN CHINA.
NOTE POSITION OF BOARD IN BOAT AND THE FISHES LEAPING FROM THE BACK SIDE OF THE BOAT. THE CHINESE ARTIST HAS SHOWN MUCH "ARTISTIC LICENSE" IN HIS DRAWING.

this mat seems to cover the open boat, it is not clear just how the fishes get into the boat. Scientific accuracy and artistic production are not in agreement here.

John Henry Gray ("China," etc., Vol. 2, p. 293. London, 1878) describes an additional device, apparently unknown or unnoticed by other recorders of this fishing method. Here it is:

> Amidships [of the boat, called *Pa-pak-teng*], a stone, which is made fast by means of a cord, is lowered into the water. In the stern of the boat the fisherman sits, and, by means of a short paddle, makes his boat glide along the waters. The course of the boat causes the stone suspended in the stream to make a rushing noise. Terrified at this, and seeing the reflection of the white board, the fish spring towards the latter, and, nine times out of ten, make such a bound as to overleap it and lodge themselves in the centre of the boat.

Gray's figure (No. 4 herein) like de Thiersant's was also drawn by a native artist—who, after the fashion of his fellow craftsman, indulged in considerable "artistic license." The board inclines not into the water but from the offside of the boat into the bottom of the boat at that side near the onlooker, and four out of five fishes seem to be leaping not from the front but from the back side across the contained board into the boat. Perhaps the moon was shining on that side of the boat.

The man in the stern wields the paddle and the boat moves forward, but there is no evidence of a suspended stone. Moreover, there is an undescribed (and uncalled for) fisherman in the bow. What he holds in his hands is not clear. It may be a noise-making device, the like of which will be referred to presently. All that one can say is that Gray's artist was liberal with his "liberties."

Coming down to more recent times, in 1909 Pol Korrigan published in "Chang-Hai" his interesting little book "Causerie sur la Pêche Fluviale en Chine." Pages 117 to 120 of this are devoted to "Les Barques à Miroir" with the figure reproduced as No. 5 herein. He notes that—"We take larks with a mirror." Then he queries—"Why should we not use it to fascinate the fishes also?" But he adds that "The Chinese have thought this matter out long ahead of us. However, the mirror used by them is not a sheet of glass from Venice, but a white-painted board."

He next states that this method of fishing is practiced sparingly in various parts of China, but most often on that section of the Grand Canal above the

Blue River. However, he found but one board and it is apparently hinged so that in case of rain it might be turned up and made to serve as a roof or cover to the boat.

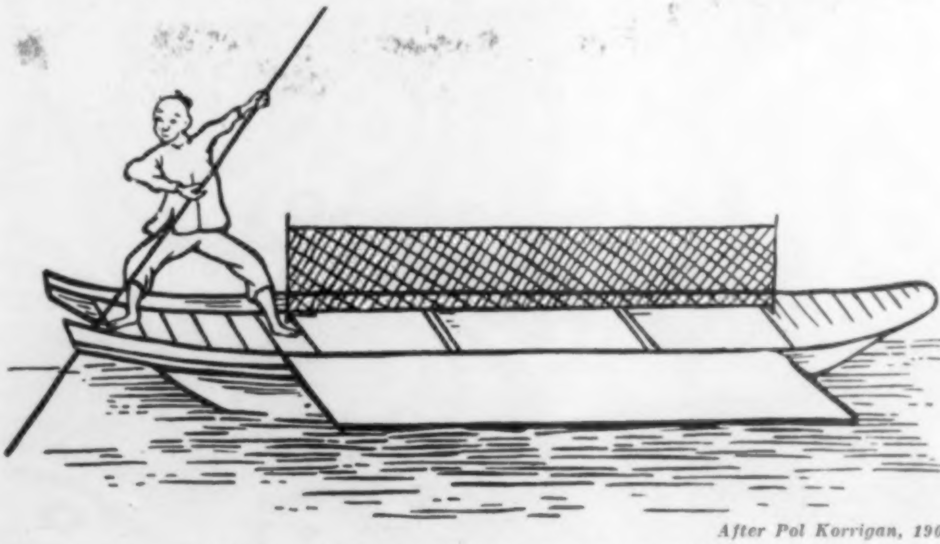
As may be seen in Fig. 5, Korrigan's native artist has portrayed a two-foot-high net set well toward the off-side of the boat. "This is to arrest the leaping fish which in its *élan,* without thought, in a vigorous leap would go beyond the *perissoire* and retomb itself in the river." An exercise which our author naïvely remarks would be "without interest to the fisherman."

Korrigan describes two methods of this fishing. In the first or soundless there is one fisherman "who fixes his barque parallel to the bank of the river with the mirror facing the width of the stream and the light of the moon." The fisherman makes no move, "he seems to be asleep and avoids making even the slightest sound." The fishes then leap and catch themselves as described above.

The other method calls for noise, and its technique is as follows: There are two men: one behind, the sculler; one forward, the noise-maker. The one keeps the boat in motion; the other taps on the planks or on a box made of tin. Thus they advance in the light of the moon. The fishes, frightened, leap "precisely on the side of the plank which shines and so into the boat."

As to which is the more successful method, the author, Monsieur Pol, avowing his ignorance, declines to asseverate, but he sagely concludes that "All roads lead to Rome."

One other figure and statement, and we leave China and the boat with the varnished board. In the *National Geographic Magazine* for September, 1919, there is the interesting present-day photograph (Fig. 6 herein) taken in China by Mr. C. D. Jameson. There is no reference to it in the text, but the caption gives the well-known description and follows with this interesting statement: "On calm bright moonlight nights, the canoe is swung out in the river across the line of an advancing school of fish. The man sits quietly waiting and the fish, dashing at the white board glistening in the moonlight, land in the canoe." This placing of the white board in the path of an advancing school of fish, so that mis-



After Pol Korrigan, 1909

FIG. 5. BOAT, BOARD, NET AND FISHERMAN.
DRAWN BY A NATIVE CHINESE ARTIST.

taking it for moon-lighted water they leap on it and then into the boat, strikes me as the soundest suggestion of how the varnished board really works. Furthermore, it looks as though the cross-pieces of the board or apron in the figure were lashed to the cross-timbers of the boat. If these crude lashings permit, it might be possible to tip the apron up and over to make a covering for the boat as previously noted by Korrigan.

It is very probable that, if other books of travel in China were examined, many other accounts and some other figures would be found. However, I have only given here such as came to my hand in the course of other work.

Use of the Board in Indo-China

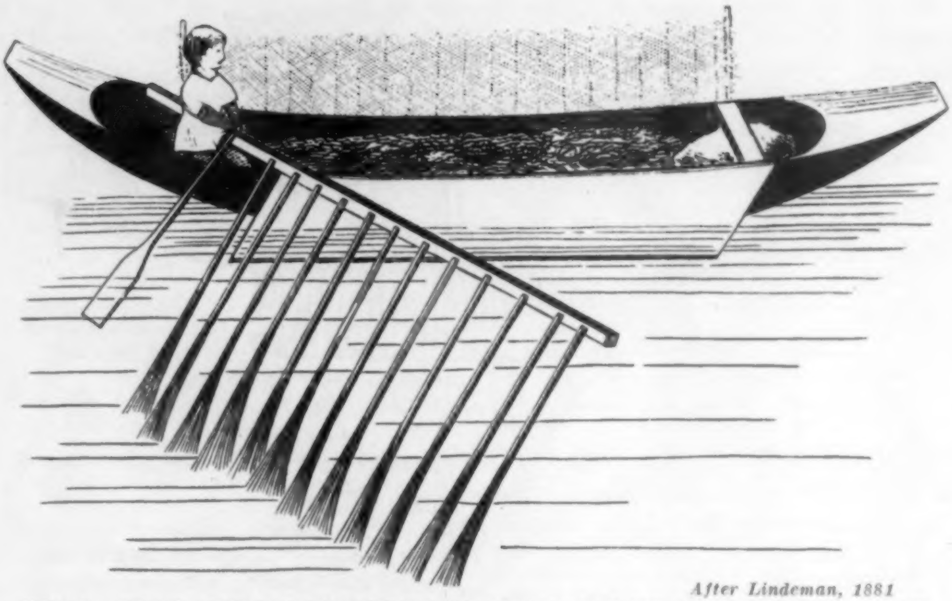
Since the Chinese have so thoroughly penetrated into the great peninsula of southeastern Asia called Indo-China, it is to be expected that this method of fishing would be found. According to Day (presently to be referred to) the use of the moon-lighted board is known "in Burmah and the East," but I have been able to find few accounts. Since these records are few, they are grouped under the above general heading, and will be listed geographically instead of chronologically.

In Tonquin

Here this fishing is carried on at night,

By courtesy of Dr. John O. La Gorce

FIG. 6. BOAT, BOARD AND FISHERMAN–PADDLER.
PHOTOGRAPHED IN CHINA BY C. D. JAMESON.



After Lindeman, 1881

FIG. 7. BOAT AND BOARD WITH IMPROVEMENTS BY THE FISHERMEN OF ANNAM.

NOTE THE FORWARDLY PLACED STONE WHICH TIPS THE BOAT TO THE RIGHT, THE *Harke* OR RAKE WHICH SCARES THE FISHES SO THAT THEY LEAP ON THE BOARD AND INTO THE BOAT, AND THE BOUGHS IN THE BOAT WHICH KEEP THE FISHES FROM LEAPING OUT.

but instead of depending on the moon to furnish the light, the fisherman carries his own. Thomas Boosey, in his "Anecdotes of Fish and Fishing" (London, 1887, p. 200), states that the fishes are attracted by means of fires toward the boats which have the usual painted boards. These, however, slope downwards (?), and when the fishes fall on them they slide into the boats. It is easy of course to see that this apparatus and its use came from the neighboring China.

IN ANNAM

At the Internationale Fischerei-Ausstellung zu Berlin, 1880, there was a display of fisheries devices from Annam. These were described by H. Lindeman in the *Amtliche Berichte* of the Ausstellung published in Berlin in 1881. On page 244 is shown the interesting "Annamitisches Fischerboot" shown in Fig. 7. The boat, whose native name is *Geh Täh*, is dug out of the trunk of a tree. The fisherman sits in the rear and propels the boat with a short oar or paddle. Forward is a heavy stone, so placed as to tip the boat so that the white board is inclined with its edge in the water. Most remarkable is the apparatus, which Lindeman calls a *Harke* or rake, and which the fisherman apparently controls. This consists of a small beam in which are set 12 rods probably of bamboo. Each of these rods is split at the outer end into from 7 to 10 filaments, hence each is like a hearth-broom. This device as it moves through the water scares the fishes. These leap on the white board and into the boat or in the case of high jumpers possibly against the mat on the back side of the boat. The floor of the boat is covered with boughs into which the fishes fall and out of which they can not leap to escape.

This "Annamitisches Fischerboot" undoubtedly has its origin in the Chinese apparatus, but there are here additional

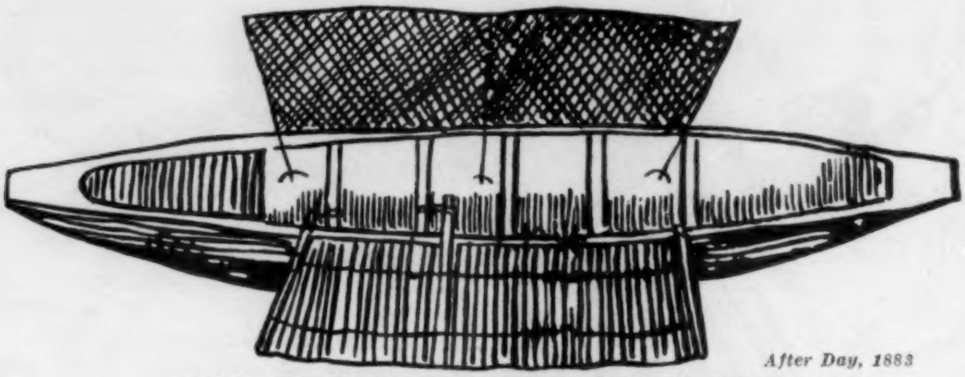

After Day, 1883

FIG. 8. THE BOAT WITH THE BAMBOO PLATFORM, USED AT CHITTAGONG, INDIA, AND IN INDO-CHINA.

devices, the stone, the boughs and the rake, which go beyond anything that the clever Chinese have invented. This device in Annam is surely an extraordinary fishing apparatus.

In Burmah

That the boat and board are used in this country is stated by Francis Day, but he gives no description of this fishing, nor have I been able to find any accounts. He states that the apparatus used is very similar to that figured and described later from India. One wishes for details and for a figure.

From Indo-China we now go first to Java on the East, and then to India proper on the west.

Fishing with the *Lokprauw* in Java

Like the Chinese, the Javanese are a very ingenious people, and like them they get their flesh food mainly from the water. These two factors in the life of the Javanese people have led them to invent some very ingenious fishing devices, among them the *Lokprauw*. This I have found described by P. N. Van Kampen in his "De Hulpmiddelen der Zeefischerei op Java en Madoera in Gebruik."[5]

The apparatus consists of a small proa, a hollowed-out tree trunk . . . along whose right gunwale a white painted platform is arranged in such a way that its free edge comes into the water. The proa is slowly rowed forth at night. The fish frightened by the bright white color of the platform, spring up and land in the proa. To hinder the jumping out of the fishes and at the same time to act as a counter-weight for the partition, there is arranged on the other side of the boat an obliquely-rising lattice-work. In Krawang the . . . the partition and lattice-work are replaced by a frame of white painted bamboo, slanting down on both sides. In Cheribon and in Djoeana the fish are said to be attracted by fire.

It should be noted that this apparatus is used certainly in the mouths of rivers and possibly out in the open sea. It is to be regretted that Van Kampen does not give more details, and particularly that he does not show a figure of the *Lokprauw*. Whether this device is indigenous to Java, or whether knowledge of it was brought from China by merchants and travelers can not be surely said. But since communication between China and Java has certainly been carried on since the days when Marco Polo and Friar Odoric traveled between those countries, it seems more than likely that this "contraption" of the Javanese is after all of Chinese origin.

The Bamboo Platform in India

Francis Day in writing in 1883 of fishing in India[6] refers to fishing boats and

[5] *Meded. Dept. Landbouw*, Batavia, 1909, No. 9, p. 98.

[6] "Indian Fish and Fishing," Handbooks Grt. Internat. Fisheries Exhib. London, 1883, No. 7, p. 50, pl. 2, fig. 13.

to one (Fig. 8 herein) which is of interest to writer and reader. He says that:

> One curious boat from Chittagong [at the head of the Bay of Bengal, and east of the mouths of the Ganges], but which is also employed throughout Burmah and the East, is fitted with a bamboo platform on one side, behind which a bamboo, having palm leaves attached, projects into the water. The fish are scared, and spring onto the platform, which is partly submerged, and on into the boat, while a net fixed on the opposite gunwale precludes their clearing the boat.

Day's description is not clear nor does his figure (copied as No. 8) clear up the description, but they are given to show that this fishing method has spread to the western edge of the Indo-Chinese peninsula, and, as we shall now see, into Bengal. Apparently the bamboo with palm leaves attached is some sort of device for scaring the fishes—like that figured by Lindeman from Annam. Unfortunately it is not shown in Day's figure.

Use of the Mat in India

As late as 1924, James Hornell in describing the "Fishing Methods of the Ganges"[7] tells of the frequent use of floating mats to catch the leaping mullets. Some of these mat-floats have barriers along the edges to confine the fishes that throw themselves onto the float, and some are used in connection with boats but at some distance away. (Devices similar to these mats were once used in other parts of the world, *e.g.*, in Scandinavia, for the same purpose.) One form, however, approximates that which has been described above. Here is Hornell's account of it.

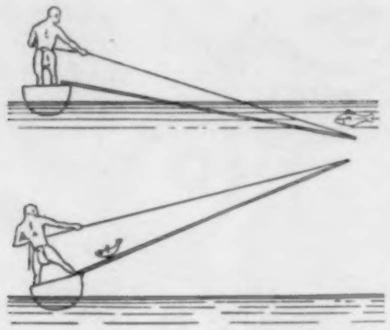
> The most highly elaborated form of this raft-trap is where the raft is much narrowed and attached in a sloping manner along one side of a canoe having this side cut down almost to the water's edge. The raft, which may be 20 feet or more in length, is not more than 18 inches wide, and is supported by a number of transverse bars of split bamboo projecting 8 inches towards the canoe to form a rough hinge arrangement in conjunction with a bamboo pole lashed along the length of the canoe. The mat, made of jute stems, is let down obliquely till its outer margin is a few inches submerged. On moonlight nights, the mullets swimming near, possibly attracted to [it] by the white gleam of the bleached jute stems, get frightened when they come actually against the mat, and try to leap it, only to fall within the canoe.

Throughout the Gangetic plain this apparatus is called *chāli* or *chānchi*. In certain districts, Hornell says that the inhabitants specialize in this *chāli* method

[7] *Mem. Asiatic Soc. Bengal*, Vol. 8 ("Fishing with Raft and Boat," p. 216).

After Burrows, 1898

FIG. 9. THE BOAT AND THE MAT USED BY THE NATIVES OF THE CONGO. THE CORDS ARE USED TO LIFT THE MAT UP.



After Burrows, 1898

FIG. 10. FISHING IN THE BELGIAN CONGO.

THE FISHERMAN, PULLING ON THE CORDS, TILTS THE MAT AND THE FISH SLIDES INTO THE BOAT.

in fishing for mullets. Unfortunately no figure is given.

It seems very probable that the inhabitants of southeastern Asia (Tonquin, Annam, Burmah and the Gangetic Plain) learned this fishing method from the Chinese. The Chinese are a far-ranging people, tenacious of their own habits of life, and using in foreign countries those practices which they have found profitable in their home country. Now, however, we go to a faraway country in which the natives have a fishing method almost identical with those studied, but which can not by any stretch of imagination be thought of as having had a Mongolian origin. And yet—!

The Mat in the "Land of the Pigmies"

There are many lands of the pigmies known to the ethnologist, historian and traveler, but that for which Captain Guy Burrows named his book (New York, 1898) is found in the basin of the Congo River in Central Africa. The author remarks that "Fish of all kinds abound in the rivers, and the natives show great ingenuity in catching them." Then without description or explanation of how it works, he illustrates on his page 265 one of these ingenious methods as shown in my Fig. 9. This mat is apparently made up of reeds like those described by Hornell above. How this apparatus is made to work is inferred from the lines fastened to the edge of the mat and of which the inner ends are held by the fishermen. In Fig. 10, found on a preceding page (251) of Burrows's work, is shown how a fish is gotten into the boat.

If the structure of the mat recalls that described for the waters of the Ganges, the work of the fishermen in drawing up the mat and spilling the fish into the boat recalls the action of Chinese fishermen as described by Staunton in 1797. This may be the long arm of coincidence, but how about this statement from Burrows (his page 84)? "The great ladies [of the Mang-bettou tribe] wear the nails of the last three fingers of the left hand very long, to show that they do no manual labor—a custom which, curiously enough, is found at the present day in Southwestern Europe and in China, due to a similar motive."

The parallelism betwixt this fishing method practised in the Congo in 1897, and that used by the fisherman in China at least as far back as 1685—251 years ago—is most remarkable. As the French say, it certainly "gives one furiously to think." However, it seems to me that we have here a fine illustration of the reasoning of Alexander von Humboldt in a study of phenomena having considerable similarity to ours. His words were something like these: "Unrelated peoples in far distant parts of the world under stress of like needs develop like processes and apparatuses to achieve the same ends."

HISTORY AND STRATIGRAPHY IN THE VALLEY OF MEXICO

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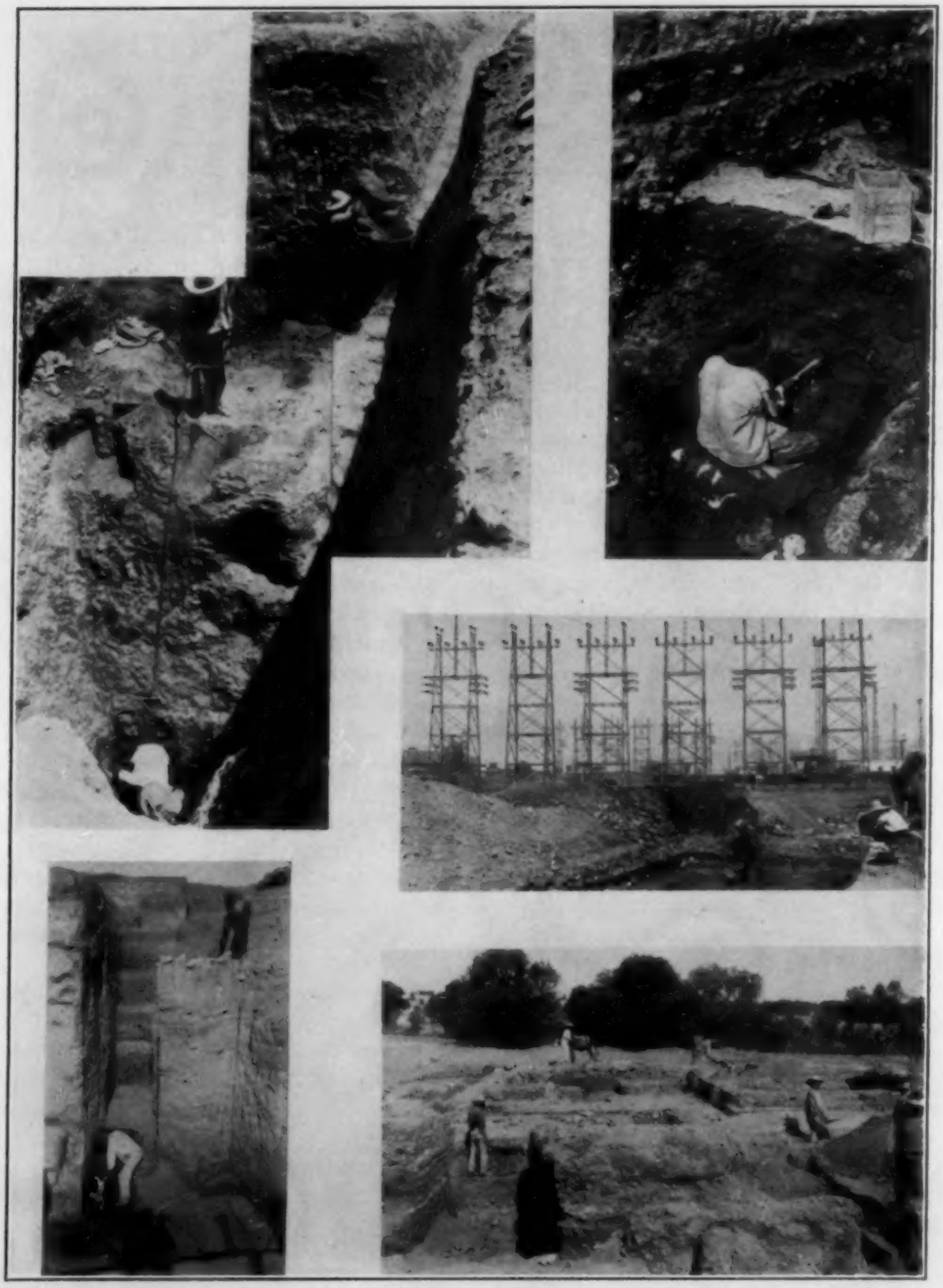
INDIAN Mexico has a past, but not a history. Thousands of mounds are scattered over the country, and in regions suitable for agriculture the plough constantly produces the shattered vessels and tools of vanished people. The modern Mexicans also show their heritage from the past. Thirty-nine per cent. of them are pure Indian, and another 53 per cent. are liberally infused with Indian blood. Even as in Italy, where both the citizens and the land which gives them life bear witness to the background of the Roman Empire, so in Mexico one feels and sees the all-pervading influence of the Indian.

Yet where the Roman past is part of the historical instruction of every schoolboy, the history of Indian Mexico is to most of us a closed book, and even the professional scholar finds that most of its pages are blank. The reasons for the gaps in the historical record are threefold: the Europeanization of Mexico, with the consequent indifference to Indian matters; the conscious destruction of native documents as idolatrous in the days of the evangelization of the country; and the rarity in Mexico of Indian tribes with a knowledge of writing which would enable them to keep historical records.

The history of Mexico, from its Conquest in 1519 to the Revolution of 1910, has emphasized the fortunes of European overlords and their relations to each other and the outside world. The overwhelming Indian preponderance in the population has been by no means balanced by similar representation in the economic and the social world. For four centuries, Europe, with all the guile and brute force of its state and with all the spiritual powers of its church, has striven to eradicate from the Indian all traces of his native culture. Since the Revolution of 1910, there has been a conscious effort to transform the Indian population from serfdom into active participation in the social and economic life of the country. With this recognition of the Indian as a potential citizen there has come in Mexico a more general esteem for the old Indian civilizations, knowledge of which had been kept alive through the ages by the untiring efforts of a handful of priests and scholars, chiefly Mexican, but including some Americans and Europeans.

These men had interpreted and preserved the few first-hand native records that had survived the wholesale destructions of documents and religious paraphernalia. They had also collected and observed the material traces of native culture dug up by farmers and treasure hunters and had tried to identify the makers of these objects and the builders of these temples by interpretation of the native annals at their disposal. It became evident, as time went on, that there was vastly more material in the ground than could be accounted for by the tribes mentioned in the historical records.

Thus in the beginning of the twentieth century, a subsidiary branch of history began to grow up, field archeology, which had for its aim the study of the Indian material culture, its history and development, and its interpretation in terms of human history. One of the chief aims of this branch of research was to try to



TYPES OF STRATIGRAPHICAL EXCAVATION IN THE VALLEY OF MEXICO.
TOP: *Left:* DEEP PIT AT EL ARBOLILLO, FEDERAL DISTRICT, MEXICO. THE EARLIEST DISCOVERED FIGURINE TYPES FROM THE VALLEY OF MEXICO WERE DISCOVERED AT THE BASE OF THIS TRENCH. *Right:* CLEANING OUT A CANAL IN THE NONOALCO DISTRICT OF MEXICO CITY. THIS SHALLOW

establish the relative age of the different monuments and cultures. Fragmentary pottery was of the greatest aid in attaining this end. Forms and decoration changed gradually with the years, and each tribe or locality had its own individual expression. By cutting into ancient refuse heaps, where the material at the bottom was necessarily laid down at an earlier date than at the top, and by carefully studying the differences in shape, texture and decoration of the fragments of pottery found, it was possible to discern the relative age of several ceramic groups. Later, by finding pottery associated with a building, the relative age of that structure could be determined. Furthermore, in Central America, it is quite common to discover that buildings are successively enlarged by filling in and adding to a previous construction, so that the stratigraphical process can be applied to architecture as well as to ceramics.

While such stratigraphical sequences have been established for various parts of Mexico and Central America, the Valley of Mexico is the first where the archeological record is detailed enough to be compared to the historical and where the two lines of research complement and check each other. Let us examine this relationship, which is one of the primary ends of archeological research.

The documentary evidence from the Valley of Mexico consists of two main types. First there were the records kept by the Aztecs and their neighbors, a few of which escaped the wholesale destructions ordered by the Spaniards. These consisted of a type of picture writing, not unlike a rebus, in which the picture of an object could represent, beside the object itself, the same sound with another meaning or as a syllable in another word. Personages and tribes were represented in this way, while events were depicted pictorially. The dates of various incidents were also given in terms of a fifty-two-year cycle, but no method of distinguishing one cycle from another was evolved. This system caused the same kind of confusion as if we were to date our history in terms of a century only, so that an event recorded as falling in "65" might mean 1065, 1365 or 1865. The Aztec picture records were undoubtedly supplemented by chants or sagas, which gave detail and color to the simple annals set forth in the manuscripts, and some of the records have notes added at a later date in Spanish or Aztec which describe the native text.

Besides these indigenous documents, there were also histories written by Spanish priests and educated Indians after the Conquest. These authors seem to have had access both to the oral traditions and the pictorial records. In most cases their original sources have disappeared or else survive in copies distorted by European draughtsmanship. These later authors were often bewildered by the native method of dating, as would naturally be the case if one lacked a complete knowledge of the events of Aztec history. Thus, by confusing the various cycles, rulers are sometimes fantastically credited with 160-year reigns. But in the main the native records are fairly complete from 1200 to the Conquest and one or two accounts, written after 1519 but based on native traditions, reach as far back as the seventh century.

DITCH WAS FILLED WITH VESSELS DISCARDED IN THE CYCLICAL DESTRUCTION OF 1507. MIDDLE: EXCAVATION IN THE NONOALCO DISTRICT. NOTE THE EVIDENCE OF MODERN LIFE CONTRASTED WITH THE ARCHEOLOGICAL SITE. BOTTOM: *Left:* PEELING LAYERS OF REFUSE AT ZACATENCO, D. F. THIS WAS THE SOURCE OF THE FIRST STRATIGRAPHICAL SERIES DEFINED BY THE AMERICAN MUSEUM OF NATURAL HISTORY. *Right:* DISSECTING AN AZTEC RESIDENTIAL STRUCTURE AT CHICONAUHTLA, STATE OF MEXICO. THIS TYPE OF STRATIGRAPHY IS FAR MORE DIFFICULT THAN TRACING THE LAMINATIONS OF CULTURE IN A REFUSE HEAP.

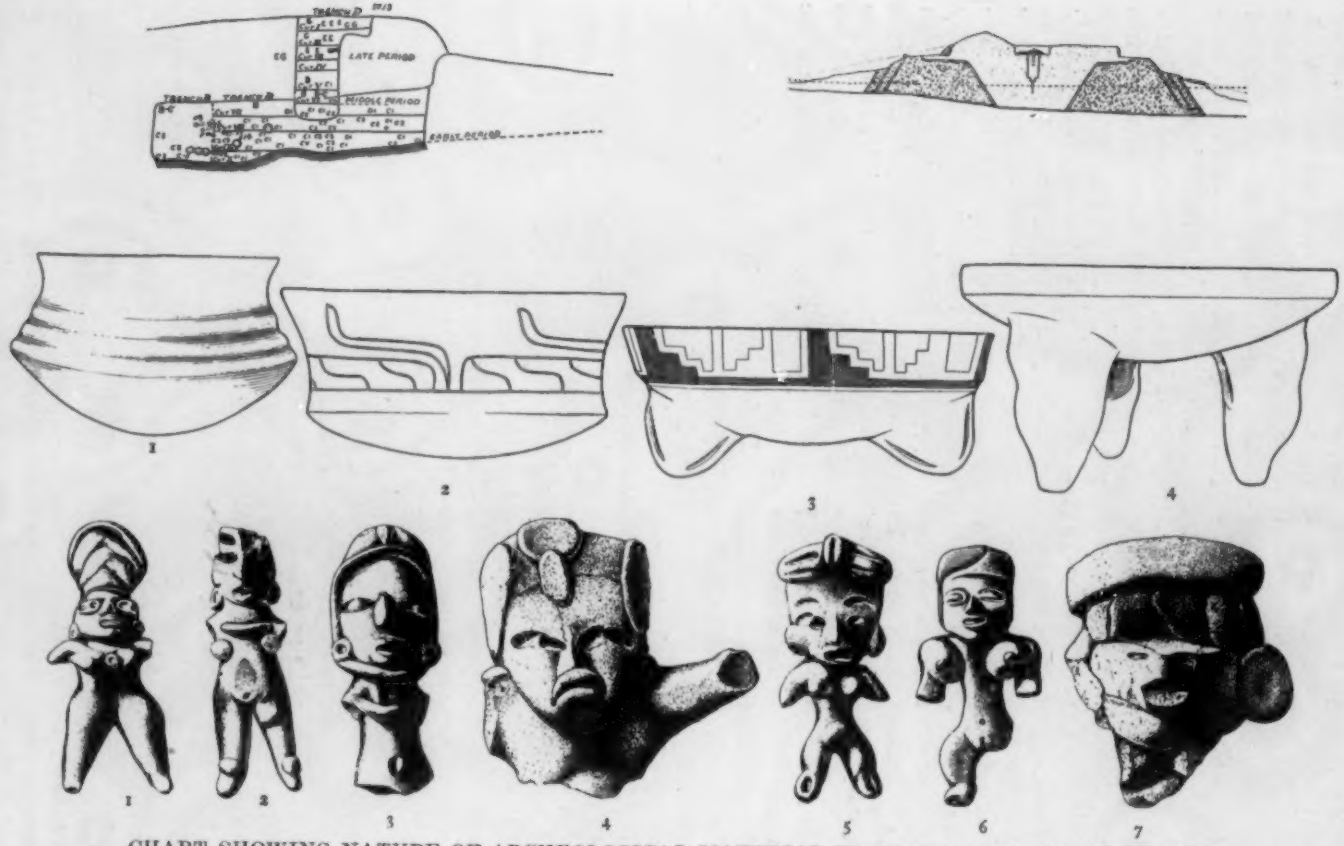


CHART SHOWING NATURE OF ARCHEOLOGICAL MATERIAL FROM THE ARCHAIC CULTURES.

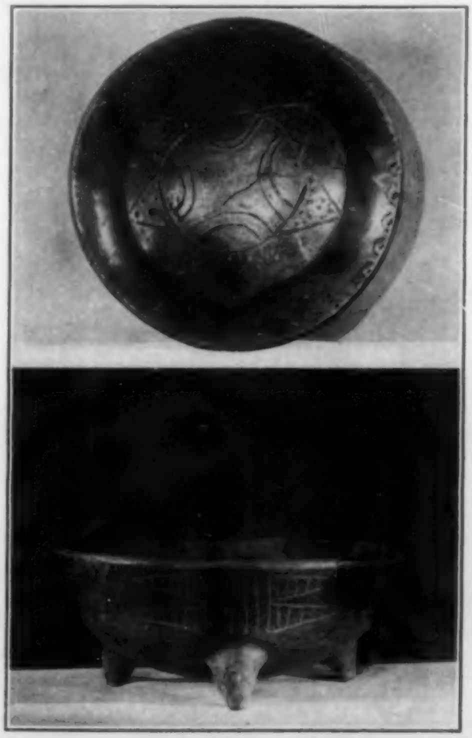
TOP: NO. 1. SECTION THROUGH REFUSE HEAP; NO. 2. CROSS-SECTION OF MOUND AT CUICUILCO. MIDDLE: FIGS. 1–2. POTTERY VESSELS FROM THE COPILCO-ZACATENCO HORIZON. FIGS. 3–4. POTTERY VESSELS FROM THE CUICUILCO-TICOMAN HORIZON. BOTTOM: FIGS. 1–4. FIGURINES FROM SUCCESSIVE STAGES OF THE COPILCO-ZACATENCO CULTURE. FIGS. 5–6. FIGURINES FROM SUCCESSIVE PHASES OF THE CUICUILCO-TICOMAN CULTURE. FIG. 7. HEAD OF ARCHAIC TEOTIHUACAN TYPE, DERIVED STYLISTICALLY FROM FIG. 5.

The history recorded for the Valley of Mexico begins with mythological tales relating to the foundation of the world and to the presence on earth of gods and giants. Then follow accounts of the Toltecs, in which the supernatural is heavily involved. The lists of their rulers do not always agree, but there is strong evidence that the Toltecs actually existed, and the Toltec era is described as a golden age in Mexican history.

Famine and the incursions of savage tribes, the Chichimecs, brought an end to the Toltec Empire in the twelfth century. One of these entities settled in Azcapotzalco and through intermarriage with the remnant Toltecs picked up enough of the earlier culture to achieve a sedentary life. At the end of the thirteenth century Quinatzin, the fourth of the Chichimec line, moved his court from Tenayuca to Texcoco; but insurrection broke out in his former dominion and thenceforth there was bitter rivalry for the control of the Valley of Mexico between Azcapotzalco and Texcoco. In the second quarter of the fourteenth century two groups of people from the Mixteca came to Texcoco bringing not only writing, but also the cult of the god Tezcatlipoca. A few years later the Tenochca, or Aztecs of Tenochtitlan the modern Mexico City, along with several other groups, filtered into the Valley and became tributary to the Tepanecs of Azcapotzalco.

At the close of the fourteenth century the Tepanec succeeded in overthrowing the Texcocans, but their sway was shortlived. In the second quarter of the fifteenth century, the deposed ruler of Texcoco raised a revolt, and enlisting the services of the Tenocheas or Mexico City

FIGURINES (TYPE C3a) FROM EARLIEST COPILCO-ZACATENCO CULTURE LAYER.



POTTERY VESSELS FROM EARLIEST COPILCO-ZACATENCO HORIZON.

Aztecs and the Tacubans, destroyed forever the political power of Azcapotzalco. These three city-states then assumed the leadership of the Valley and by a series of conquests enlarged their power to cover great sections of southern and eastern Mexico. Gradually the Aztecs supplanted the Texcocans as the dominant political power in the league, but the cultural and intellectual leadership still remained with Texcoco. At the time of the Conquest the Aztec dominion was at its height, but the disaster in store for it at Spanish hands was but an acceleration of the seething hatred felt by the subject people who allied themselves speedily with the white invaders.

This history, culled from documentary sources, resolves itself into several stages or periods:

(1) The legendary period of the foundation of the world.
(2) The Toltec Empire.
(3) The Chichimec period.
(4) The formation of the Texcocan kingdom.
(5) The rise of the Aztec Empire.

We must now see how this pattern compares with the sequence of cultures, derived by excavation. This latter process has been a long one, lasting over twenty-five years, and still is not complete. While the Department of Monuments of Mexico and the American Museum of Natural History have been most active, yeoman service has been done by the now-disbanded International School, the Stockholm Museum and the University of Arizona. Now the point has been reached where a correlation can be made between the tribes of the Valley and their material culture.

Traces are found of five main culture levels, differing from each other in the form and decoration of their pottery, in the artistic styles of their stone and clay sculptures, and in their architecture. Through the study of the strata in the rubbish heaps, minor time stages can be distinguished within each culture group.

The earliest traces of man were originally found beneath a lava flow at the south of Mexico, but careful stratigraphical analysis of rubbish heaps in the Guadalupe hills, northeast of Mexico City, where similar material was found, revealed a long history for these finds, which resolved themselves into the handiwork of two peoples. The earlier culture, named Copilco-Zacatenco, after the sites where first found, showed five stages of development, represented in twenty-foot accumulations of refuse indicative of a long lapse of time. The general culture level was on a par with that of the more developed of our North American Indian tribes. The later finds, called Cuicuilco-Ticoman, could be divided into three time stages, derived from refuse heaps that, although deep, could not compare to the earlier deposits. In the Cuicuilco-Ticoman culture there were to be seen evidence of a considerable advance in handiwork, for not only were pottery, figurines and stone tools better made and in greater variety than in the preceding periods, but also the presence of mounds and unquestionable representations of gods indicated the beginnings of a formalized religious system. The wide geographic distribution of this culture shows that these remains were the handiwork of an important and populous tribal group.

The third horizon is marked by the finds made at the great pyramid city of San Juan Teotihuacan, northeast of

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SPECIMENS FROM THE ARCHAIC CULTURES.
TOP: *Left:* MOTHER AND CHILD FROM CUERNAVACA MORELOS. *Center:* PYRAMID OF CUICUILCO, D. F., NOTE THE LAVA ENCROACHING ON THE MOUND. *Right:* FIGURINE, CUERNAVACA, MORELOS.
MIDDLE: *Left:* LARGE HOLLOW FIGURINE, CUERNAVACA, MORELOS. *Right:* HEAD, ZACATENCO, D. F.
BOTTOM: POTTERY VESSELS OF THE CUICUILCO TICOMAN CULTURE, TICOMAN, D. F.

Mexico City. While the earliest of the five periods tentatively defined shows affiliations with a branch of the Cuicuilco-Ticoman culture, the pottery and figurines present a rapid advance in technique and artistic value. Designs are often derived from ceremonial motives and testify that already that ritualistic preoccupation which so characterizes Central American civilization had taken form. Mighty pyramids and elaborate palaces give evidence of a closely knit social organization able to draft man-power to achieve such ends, while excellent stone sculptures indicate good craftsmen and trade with adjacent cultures. The last phase of this civilization is found at Azcapotzalco, apparently after Teotihuacan had been abandoned. Figurines were made in moulds, suggesting a curious use of mass production to satisfy the needs of mass religion, but architectural remains at Azcapotzalco reveal none of the grandiose qualities of Teotihuacan.

These first three culture groups have shown a slow development that reaches a peak in the civilization of Teotihuacan. The artistic forms and styles do not evolve progressively, but rather in jerks, as one tribe seems to have driven out another. The most violent change occurs with the introduction of the fourth culture period. Here, at San Francisco Mazapan, a simple complex of human handiwork is found overlying the Teotihuacan remains. While sporadic pieces, presumably obtained by trade, attest to the presence of relatively high civilizations elsewhere, the bulk of the material reveals little evidence of ritualistic, social or artistic advancement. By studying the traded vessels, connections are obtained with a series of other peoples, some of high and some of low culture, some inhabiting the Valley of Mexico and others as far away as Yucatan. It is as though with the collapse of the Teotihuacan civilization, a number of other tribes had risen to power and filtered into the countryside.

The last culture stage constitutes the articles of household and ceremonial use, the sculptures and the architecture found in places known to have been occupied by the Aztecs. One very characteristic ware may be divided into six periods, while other local forms and decorations reflect the presence of city-states mentioned in the chronicles.

The six Aztec pottery periods may also be grouped into larger units. The first period has been found in quantity at only one site in the Valley, Culhuacan, and stylistically these ceramics show affiliations with Cholula and the Mixteca, and, by trade pieces, with Mazapan. The second and third periods are closely united, and only minor differences in their coarse style of draughtsmanship distinguish them. The fourth and fifth periods produced highly conventionalized designs that are very similar, but many highly decorated polychrome wares attest to a wide trade. The last period styles evolve from the preceding but with a new element of naturalistic decoration.

Here then is the logical starting point for a correlation between the archeology of the Valley and its documentary history. If the six ceramic periods could be tied in with the annals of the Aztec, then there would be a fairly secure basis for testing the vaguer portions of the Valley's past. To this end a curious custom of the Aztec gave us a very good lead.

The Aztecs at the close of each of their 52-year cycles broke all their household utensils and put out their fires. Then they refurnished their houses and made new equipment. Presumably the temples and sacred buildings underwent a similar renovation. After midnight on the last day, a new fire was kindled on a hill outside of Mexico, and runners with torches distributed this flame to all the hearths in the Valley, while every one rejoiced that life was to continue for another 52-

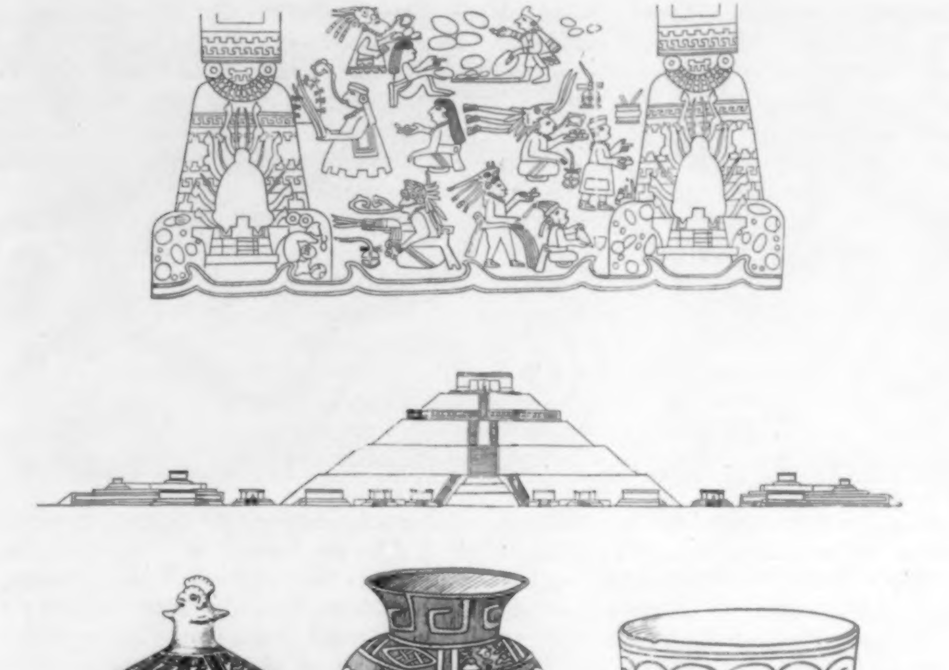


CHART SHOWING NATURE OF MATERIAL FROM THE TOLTEC CULTURE.
First Row: Fresco from Teotihuacan, showing people involved in a ritualistic ceremony. Second Row: Reconstruction of the Pyramid of the Sun at Teotihuacan, after Gamio. Third Row: Pottery vessels, Toltec Culture. The last is later than the first two. Fourth Row: Successive stages of figurine manufacture in the Toltec Culture. The last two are mold-made.

year span. The native chroniclers record this practice punctiliously, for the Mexican calendar system was a sacred almanac for governing men's lives and served only secondarily as a means of recording time.

Reflections of this ceremony have been found in excavations around Mexico City, where broken pottery and idols were found in too great quantity to have been the result of accidents. Ancient temples, in which the successive additions give the nested effect of a Russian doll, also suggest a further application of this practice.

One of these cyclical dumps yielding pottery of the fifth Aztec style we uncovered last spring in the heart of Mexico City, at the power plant of Nonoalco. A normal refuse heap of the sixth and latest style lay above the ceremonial deposit. Since this latest type of Aztec pottery occasionally shows such traces of Spanish influence as glazed surfaces and European designs, it must have been in vogue at the time of the Spanish penetration of Mexico subsequent to 1519. Therefore we had good basis for assuming that the lower layer of the fifth period represented the destruction in connection with the last New Fire Ceremony before the Conquest, which was celebrated in 1507. Moreover, at Chiconauhtla, a frontier town of the Texcocan dominion, we found another ceremonial dump of this same fifth Aztec style under circumstances which proved it to have been made at the end of the occupation there.

To strengthen our hypothesis we found two dumps of the fourth Aztec ceramic period, one at Chiconauhtla and another in Texcoco itself, an occurrence which would suggest the celebration of the New Fire Ceremony 52 years previous, or in the year 1455 (1507–52 = 1455). In one of the earlier buildings at Chiconauhtla, we came across another such dump composed of pottery of the third Aztec period, which, if our hypothesis was correct, would represent the cyclical destruction of 1403.

The second Aztec pottery stage was obtained from a low stratum of a normal refuse mound at Chiconauhtla, so that while we have no definite evidence that this earlier stage should span another 52-year period, we have some right to assume it was made between 1299 and 1351. Furthermore, the first Aztec period, as we have said, is found in quantity at only one site in the Valley, Culhuacan, and may well be contemporaneous with the Mazapan culture described above as representing the fourth epoch in the development of civilization in the Valley.

According to our reckoning, then, the Period 6 style, from 1507 to the Conquest, represents the last days of the Aztec Empire. Pottery of Period 5, which was made between 1455 and 1507, is widely distributed as befits the domination of the Aztec League. The method of decoration in vogue in Period 4, 1403–1455, is strongly represented at the palace of Nezualcoyotl, the great Texcocan ruler, and at Texcoco itself. At this time Texcoco rather than Tenochtitlan led in sumptuousness and splendor. The trade wares suggest tribute from the conquests of that era and the clay idols reproduce the wide variety of gods in the Mexican pantheon.

Pottery from Period 3, 1351 (?)–1403, is scantily represented at Tenochtitlan, which in this period was a weak tributary to Culhuacan and the Tepaneca of Azcapotzalco, but this style, like that of Period 2, 1299 (?)–1351 (?), is found in the other Valley centers. During the fourteenth century, as we have seen, the Tepanecs, Texcocans and Culhuas held the leadership of the Valley of Mexico, and the pottery attributable to this period is most commonly found in the towns under their dominion.

Confirmatory evidence of the reflection of time in ceremonial practice is

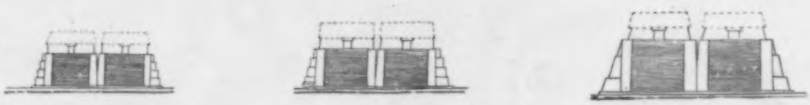
Photograph by Le Rochester

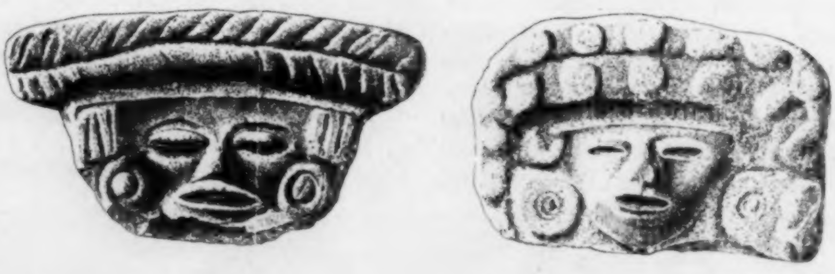
PYRAMID OF THE SUN AT TEOTIHUACAN, STATE OF MEXICO.

yielded by the pyramid of Tenayuca, where seven buildings are found superimposed. The last reconstruction presumably marks the ceremonies of 1507, the next two in the same style, those of 1455 and 1403. The architecture of the fourth (1351) is transitional to two more primitive pyramids possibly representing the ceremonies of 1299 and 1247 which corresponds very well to the early thirteenth century date given to the founding of the Chicimec kingdom in Azcapotzalco. The break from the primitive to the regulation Aztec style of architecture accords well with the historical data, which describe Quinatzin's becoming civilized and moving to Texcoco in 1298 and the arrival of Mixtecs and other tribes in 1328. A resemblance, too close to be entirely coincidence, exists between the tradition of the Mixtecs having brought knowledge of writing in 1328 and the Period 2 and 3 style of decoration which seems based more upon the fluid principle of writing than the previous labored method of painting designs in geometric fashion.

We have traced our way to the last half of the thirteenth century. Our records have become very hazy, and we now meet

TOLTEC FIGURINES. NOS. 1–5, TEOTIHUACAN II (EARLY TOLTEC) TYPE. NOS. 6–7, TEOTIHUACAN V (LATE TOLTEC) TYPE. NOTE IN NOS. 3–4 GROTESQUE FEATURES INDICATIVE OF SYMBOLISM DEFINING VARIOUS DEITIES.





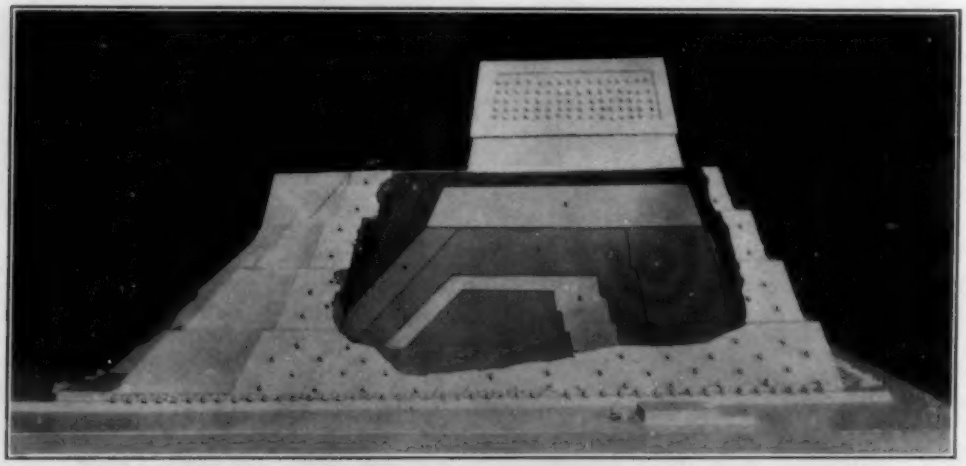
the Mazapan culture, the fourth level in the Valley. The chronicles tell of the incursions of the Chichimecs, who brought an end to the Teotihuacan culture some time in the twelfth century. We can rely no longer on ceremonial dumps, but we can achieve a relative dating in another way. Two trade wares are found in the Mazapan culture, Plumbate, a natural glazed pottery perhaps made in Salvador, and Fine Orange, which is common on the Isla de Sacrificios in Vera Cruz. Both these wares are frequently found in Chichen Itza in refuse of the Mexican period, which began about 1200 A.D., and lasted until 1458. That the Mazapan culture flowered in the thirteenth century seems extremely probable both because of its stratigraphical position below the Aztec-Texcocan material remains and above those of Teotihuacan, and because of the trade pottery which ties in with thirteenth century refuse heaps at Chichen Itza in Yucatan. The makers must then be some branch of the Chichimec immigrants, who, arriving in Mexico during this period, seem to have assumed distinctive tribal names even as, in adopting a sedentary life, they occupied fixed places of residence.

Following our method of elimination there seems no reasonable doubt that the Toltecs were the makers of the Teotihuacan civilization, a thesis which is supported by a great deal of legendary evidence. The long span of the 700–1200 A.D. dates assigned by some to the Toltec Empire agrees well with the traditional evidence and the retarded cultural de-

LIFE-SIZE POTTERY EFFIGY FROM COATLINCHAN, STATE OF MEXICO. STYLISTICALLY THIS FIGURE SEEMS TO BELONG TO THE MAZAPAN CULTURE.

CHART SHOWING ARCHEOLOGICAL MATERIAL FROM THE CHICHIMEC CULTURES. TOP ROW: HISTORICAL PICTURE WRITINGS RELATING TO PERIOD. 1, CHICHIMEC HUNTER. 2, AZTECS SETTING FORTH ON THEIR WANDERINGS. 3, EIGHT TRIBES WHO SETTLED IN AND AROUND THE VALLEY OF MEXICO. SECOND ROW: SUCCESSIVE STAGES IN THE CONSTRUCTION OF THE TEMPLE OF TENAYUCA WHICH EPITOMIZES THE ARCHITECTURE OF THE CHICHIMEC AND AZTEC PERIODS. THIRD ROW: POTTERY STYLES OF MAZAPAN, COYOTLATELCO AND AZTEC I TYPE WHICH MAY EVENTUALLY BE CORRELATED WITH SOME OF THE TRIBES SHOWN IN TOP ROW (3). FOURTH ROW: FIGURINES OF COYOTLATELCO TYPE. FIFTH ROW: FIGURINES OF MAZAPAN TYPE.

TEMPLE OF CHOLULA, PUEBLA.
BENEATH THIS LARGE ADOBE PLATFORM IS A COMPLEX OF BUILDINGS OF THE TOLTEC PERIOD.



MODEL OF THE TEMPLE AT TENAYUCA, D. F.
SHOWING SUCCESSIVE RENOVATIONS MADE IN CONNECTION WITH THE RENOVATION CEREMONIES AT THE BEGINNING OF CALENDAR CYCLES. THE SIX BUILDINGS SHOWN MIGHT CORRESPOND TO STRUCTURES MADE IN 1507, 1455, 1403, 1351, 1299, 1247.

velopment one would expect of people who could not borrow but had to invent each material and cultural innovation. Furthermore, this hypothetical dating is roughly substantiated by the discovery of the Swedish archeologist, Linné, who found, in a Toltec building on the outskirts of Teotihuacan, Peten Maya trade pottery like that associated with the dated Maya monuments (*circa* 433–889).

While the historical position of the Valley of Mexico Toltecs seems to be fairly well established by the correlation of archeological and historical data, there is still confusion attendant to the cultural identification of people called by the same name in other districts of Mexico. Further research should clear up the identity of these tribes, as either colonists driven out of the Valley or outlying branches of the same group who retained their tribal organization although modifying their culture, or perhaps people completely different culturally and tribally who were given this name as a generic distinction, even as the discoverers of America called its inhabitants Indians.

With this final identification, connection between traditions and archeology ceases, so that we can not identify the makers of the Cuicuilco-Ticoman and Copilco-Zacatenco cultures, often grouped under the term "Archaic." True, the mythology records giants as inhabiting the earth before the advent of the Toltecs, but the skeletons found in graves of these periods give no evidence of extraordinary size. It would be tempting to align with mythical destructions of the world the rise in lake level which affected the Zacatenco culture or the lava flow from the Pedregal which surrounded the ruins of the Cuicuilco pyramid. As these successive destructions were by Jaguars, Wind, Fire and Water, the order is wrong for such an interpretation of the geological disturbances affecting the Early Cultures, but it is possible that a vague folk memory of such events may have been incorporated in the myths.

The dating of these Early Cultures is impossible in an absolute sense, but, relatively, some estimate may be made. The geologists all agree that the lava flow is recent, but their computations of 2,000 to 8,000 years are meant to be taken in

UPPER: POTTERY EFFIGY VASE FROM MAZAPAN STATE OF MEXICO. LOWER: TWO BOWLS OF PLUMBATE WARE FROM MAZAPAN. THIS IS AN IMPORTANT WARE FOR CROSS DATING CULTURE PERIODS.

the geological sense of extreme youth instead of the historical sense of great age. There is some evidence that the Ticoman-Cuicuilco culture is partially contemporaneous with Teotihuacan. It is also possible to compare the accumulations of rubbish at Zacatenco and Ticoman with those of a site in New Mexico, Pecos, the

CHART SHOWING ARCHEOLOGICAL MATERIAL FROM THE AZTEC CULTURE.

FIRST ROW: SCENES FROM HISTORICAL PICTURE MANUSCRIPTS. (1) ARRIVAL OF NATIONS WITH THE KNOWLEDGE OF WRITING IN 1325; (2) NEW FIRE CEREMONY OF 1403; (3) NEW FIRE CEREMONY OF 1455; (4) NEW FIRE CEREMONY OF 1507; (5) THE TAKING OF TENOCHTITLAN (MEXICO CITY) IN 1519. SECOND ROW: SUCCESSIVE STAGE IN THE ARCHITECTURE OF THE TEMPLE AT TENAYUCA CORRESPONDING PERHAPS TO THE RENOVATIONS OF 1403, 1455, AND 1507. THIRD ROW: (1–3) AZTEC POTTERY TYPES (II, IIIa, IIIb) FOUND IN THE CYCLICAL DUMPS FOR 1403, 1455, AND 1507. (4) POTTERY TYPE (IV) MADE FROM 1507 UP TO THE CONQUEST. FOURTH ROW: (1–2) AZTEC FIGURINES MADE PRIOR TO 1403. (3–6) AZTEC FIGURINES MADE BETWEEN 1403 AND THE CONQUEST.

AZTEC POTTERY TYPES.

TOP: TRICHROME VESSELS FOUND IN A 1403 CYCLICAL DUMP AT CHICONAUHTLA. MIDDLE: *Right:* TRADE BOWL FOUND IN 1507 DUMP AT CHICONAUHTLA. *Left:* LOCAL TRICHROME BOWL FOUND IN THE 1507 DUMP AT CHICONAUHTLA. BOTTOM: *Left:* ORANGE ON RED BOWL WITH BLACK OUTLINE FROM NONOALCO. *Right:* BLACK ON ORANGE DISHES FROM NONOALCO.

occupation of which is accurately known in years by means of the tree ring method. Dividing the number of years by the greatest depth of continuously deposited debris at Pecos, one gets a ratio of 78 years to the meter. Applying this computation to the deepest refuse heap at Ticoman, one finds 286 years of accumulation, and to the thickest middens of the Copilco-Zacatenco culture, 787 years. Perhaps a thousand years is excessive, so that computing on the basis of the deepest bed which shows continuous occupation by both cultures, one arrives at nearly 600 years for the total length of habitation.

Rough and inaccurate as these computations are they indicate that the Valley of Mexico was inhabited for a long time before even the dimmest historical records, and that the earliest remains so far recovered were made in the first centuries before the Christian Era. However, these early people were by no means primitive. Indeed they were on a par already with our modern Pueblo, and there are many stages of culture to be discovered and analyzed before we can say we have traces of the earliest man in Central America.

This article has endeavored to sketch one phase of historical research on the past of Mexico. A major problem has been to bridge the gap between the peoples who are identified by Spanish and Indian documentary records and those who are known to us only through the ruins of their buildings and the broken elements of their material culture which have survived. While at times it must seem as though the archeologists labor to make bricks without straw, yet the results of the Valley of Mexico research prove that it is possible to formulate a history with the meager data provided. In Yucatan, Guatemala and Oaxaca, similar methods have sketched the main outlines of historical development. Even if the history thus obtained discloses little or nothing of the life of the individual, it does throw abundant light on the steps by which man achieves his artistic development and economic progress. The lesson is constantly driven home that greater than man is the sum total of his achievements.

SOME NEGLECTED ASPECTS OF PLAGUE MEDICINE IN SIXTEENTH CENTURY ENGLAND

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For the historian few subjects fail to profit from a reexamination and a restatement of pertinent data, and plague medicine proves no exception to this generalization. While historical revisions often bear some characteristics of a lark—a rather pedantic lark, to be sure—they generally convey more than an antiquarian interest and express more than a mere erudite whim. Generations of historians and shoals of other writers have, whether intentionally or ignorantly, fastened upon the political and medical authorities of the sixteenth and seventeenth centuries a genius for ineptitude, stupidity and even deliberate cruelty. A statement made recently by a competent historian in connection with the plague of 1665 that "beyond insisting on isolation and prohibiting the holding of the great fairs, the government did little," is one of the gentlest criticisms of public policy. Much oftener writers scornfully denounce the "optimistic credulity" of these earlier days in contrast to the "sceptical science" of our own, and they even deplore the omission of policies which many governments to-day would hesitate to put into effect in their entirety. Such critical and scornful hindsight illustrates only too well the practice of reading history backward.

Considerable and varied evidence, however, indicates that this view-point does not comprehend the whole story. During the sixteenth century the magistracy, both local and central, often tried to combat the plague by methods that might well gain the applause of a modern health officer. In order to appreciate that fact the gleanings of numberless records are necessary; but from these come the realization that preventive medicine was not born yesterday. Too long have the quaint recipes and prescriptions, interesting and significant though they may be, been allowed to describe the quality of sixteenth century medicine, and for that matter the character of pre-nineteenth century science as well. Yet these no more provide an adequate account than the assumption that patent drugs or folklore remedies comprise all of modern medicine. The bumptiousness of much recent popular science has encouraged many people to assume that before some vaguely generalized epoch like the world war all was darkness and barbarism. Popular writers, and others who ought to know better, forget that modern medicine, which of itself may or may not be so very *scientific,* stands on the shoulders of earlier medicine which may or may not have been so very unscientific. As it takes more than a few test-tubes to make a modern doctor, it took more, or perhaps less, than their absence to make a sixteenth or seventeenth century quack.

Bizarre methods of combating the plague prevailed of course in all sections of the country and in all strata of society, but alongside these seemingly ridiculous antidotes stood the careful, intelligent observations of men who had a fair claim to be considered the harbingers of a more scientific medicine. Medicine based on acute observation and exact experiment was by no means the exclusive product of the nineteenth century, nor has it entirely superseded prac-

tices which snobbery pleases to designate as medieval. Whatever the approach to the medical ideas and practices of an earlier day, comparisons must be made between similar groups. Writers should compare old wives' tales and modern quackery, not old wives' tales and the Mayo clinic. If they wish to emphasize medical progress, they should not compare Banting with some nameless apothecary who with all his nostrums menaced his customers no more than the manufacturers and vendors of Ex-lax or Father John's Medicine injure theirs, and probably did it less expensively. So, as the thousands of yesterday were oftenest prone to depend on recipes which they knew best and could get the easiest, the millions of to-day attempt to secure pep or good temper or healthy nerves or a trim figure by a treatment no more rigorously clinical than that used by their ancestors.

Moreover, in respect to what appears a credulous way of defeating the plague by laying the belly of a live frog or the rump of a live cock chick to a plague sore it may be mentioned that all contemporaries did not take such methods over-seriously. For example in 1561 there appeared the following parody on such nostrums (spelling modernized):

Take a pound of good hard penance, and wash it well with the water of your eyes, and let it lie a good while at your heart. Take also of the best fine faith, hope and charity that you can get, a like quantity of all mixed together, your soul even full, and use this confection every day in your life, while the plagues of God reigneth. Then, take both your hands full of good works commanded by God, and keep them close in a clean conscience from the dust of vain glory, and ever as you are able and see necessity to use them. This medicine was found written in an old bible book and it hath been practised and proved true of many, both men and women.

As Macaulay's omniscient school-boy would know, the plague had been visiting England for centuries before the last great epidemic in 1665. During the seventh century—to go no farther back—it raged extensively for twenty-five years after the Synod of Whitby (664), driving large numbers of people back to paganism and at the same time disorganizing society and politics. In the millennium that followed the plague made innumerable visitations, of which the most famous was that of 1349, although many others had consequences scarcely less disastrous for limited areas. Full testimony has survived concerning the effects of the most extensive of these epidemics, and in the case of the Black Death writers have not hesitated to attribute every sort of disaster to its destructive blight. Later plagues have not been credited with such revolutionary consequences, possibly because they came with such frequency that familiarity may well have consummated its proverbial destiny and have bred contempt in the minds of contemporaries. Yet contemporary indifference should not be taken as evidence of no influence, for in any case the efforts at control indicate realization of potential disaster.

As early as 1518 the government drew up and enforced orders for the prevention of plague in London. The city magistrates bore the brunt of the responsibility, but the constable actually carried out the orders by reporting to the mayor the number who died, by closing and marking the houses of the infected and by arresting the beggars and idlers. In addition, special officials called "examiners" were appointed to keep an eye on the state of the plague. The authorities did not stop with this, however; they ordered that no clothes or bedding about any infected person should be sold or given away. They likewise enforced segregation, a policy more or less in force since the Black Death. Feasts and assemblies were postponed, infected persons were forbidden to attend church, theaters were closed, houses visited by the infection were marked with a red

cross and an inscription, "Lord have mercy on us," for forty days, and no inhabitant of these houses was allowed to leave the house without carrying a white rod four feet long. These rules or variations upon them applied during subsequent visitations, but the authorities did not rest content with them, for new measures were constantly introduced. In 1535, for example, no one was allowed to bring oysters into London, on pain of imprisonment; and during the next few years, in order to prevent the spread of the infection, royal proclamations frequently denied people access to the court and adjourned the law courts.

By the middle of the century other restrictive policies were in practice. In 1547 the Privy Council required all persons in whose houses the plague had visited to put a cross on their street door. Burial regulations became steadily more strict. The government prohibited crowds from gathering at funerals and commanded the curates and others that no corpse should be buried before six in the morning or after six at night and that there should be at least one bell rung at the burial of every corpse. The authorities likewise investigated improper methods of burial, but here they did not accomplish much, because burials were bound to be hasty on account of inadequate facilities and inasmuch as parish churchyards could not possibly contain all the plague-stricken dead. Moreover, corpse bearers employed at a stipulated wage were required to carry red wands when they passed along the streets.

The terrible inroads made by the plague during the early years of Elizabeth's reign compelled constant and exhaustive efforts at relief. In August, 1563, the council warned lest returning soldiers spread the infection, and in the following March ordered the officers of Westminster to shut up all houses visited by the plague and see to it that the inmates did not venture out. At the same time magistrates collected money for the quarantined poor and sought to prevent crowding.

Shortly afterward the Mayor of London commanded every one to draw ten buckets of water before six in the morning and pour them in the streets and gutters. The streets were to be swept every day before six in the morning and after six in the evening when the gutters were to be cleaned. Scavengers were to remove the filth from the street every second day at least. Because of the conviction that dogs carried the plague from house to house he appointed special officers to kill and bury dogs found loose between 10 P. M. and 4 A. M. Cats, rats, swine and pigeons were also thought to be very dangerous, and steady efforts curtailed their carrying activity. Likewise, the mayor commanded every man in every street and lane to make fires three times in the week and appointed two poor men to burn such straw, clothing and bedding as they should find in and near the city whereon any plague-stricken person had laid or died. He ordered an inquiry into the number of persons who had died of the plague in the various parishes; he required the church wardens to give notices of plague-infected houses, to forbid every person therein coming to church for one month following the visitation, and to fix a blue cross upon the door; and he commanded the plague-stricken persons to remain constantly in the house, with doors and windows shut, for forty days. Finally, orders gave directions for preventing infection and fumigating the houses as well as describing symptoms and suggesting remedies.

Although these measures only affected London, preventive measures were by no means limited to the capital. At Liverpool, where narrow, ill-kept streets and defective sewerage no doubt had much

to do with the prevalence of the scourge, several orders went into effect. In 1558 the magistrates ordered that all persons struck by the plague should leave their houses and set up their abode outside the city on the heath. Those who did not leave were "to keep on the back side of their houses, and keep their doors and windows shut on the street side until such time as they have licence from the mayor to open them," and no other persons were to dwell with them. In 1562 it was found "very expedient that all dunghills and middings be clearly and clean taken away." Winchester and several other towns halted their fairs. At Maidstone the authorities addressed themselves to the difficult and common problem of caring for the sick. Often the healthy ran off, leaving the victim, who perhaps in the end might die of starvation rather than of the plague itself. Therefore, the mayor or his deputy could appoint persons dwelling in the town almhouses "to do ther true endevour, dylygence and servyce for the comforte, helpp and succour of the syck." In case of refusal such persons could be turned out of the almshouse. In 1565 the privy council, considering that the two universities were "instituted for the education of youth, and maintenance of such as teach the liberal sciences, . . . good means should be used to preserve them in peace, and to keep them free" from infection. Therefore Cambridge University was charged to have good regard that no open shows be made and to suffer no assemblies of vulgar people who might bring the infection, within that university or five miles compass.

Such provisions, however, ought not to be taken as the full measure of antidotal legislation, and it would be less than historical to neglect, in passing, the fact that the help of God was not scorned. In 1551 the king desired the bishops to exhort the people to a diligent attendance at Common Prayer and so avert the displeasure of God who had visited the realm with the "extreme plague of sudden death." Then there was also the special prayer in the Book of Common Prayer: "In the tyme of any common plague or sickness O Almighty God . . . have pitie upon us miserable synners, that nowe are visited with great sickness and mortalitie. . . . So it maye now please thee to withdrawe from us thys plague and grevous sickenesse, throughe Jesu Chryste oure Lorde." In 1564 the council proclaimed a thanksgiving for release from the plague.

Probably an even better example of this attitude of mind was to be found in the letter of Queen Elizabeth to Archbishop Parker in 1562.

> Considering the state of this present time, wherein it hath pleased the most highest, for the amendment of us and our people to visit certain places of our realm with more contagious sickness, than lately hath been; for remedy and mitigation whereof, we think it both necessary and our bounden duty, that universal prayer and fasting be more effectually used in this our realm. And understanding that you have thought and considered upon some good orders to be prescribed therein, for the which ye require the application of our authority, for the better observation thereof amongst our people; we do not only command and allow your zeal therein, but do also command our manner our ministers ecclesiastical or civil, and all other our subjects to execute, follow, and obey such godly and wholesome orders, as you being primate of all England, and metropolitan of this province of Canterbury, upon godly advice and consideration, shall uniformly devise, prescribe, and publish for the universal usage of prayer, fasting, and other good deeds during the time of this visitation by sickness and other troubles.

Admitting, however, that prayer and fasting were frequent methods of combating the plague, it must be remembered that they generally were substantiated by concrete preventive action. In October, 1568, the authorities restricted the visits of outsiders to London and during the following year limited the movement of people about the country, even going so far as to halt all traffic between Lon-

don and Windsor. In fact, a good many men and women, chiefly vagabonds, were whipped for not obeying these restrictions and who were therefore regarded as spreading the plague. Moreover, fairs were prohibited, courts adjourned and the sale of fruit forbidden on the London streets. Both the Privy Council and the town governments never ceased to consider how the spread of the plague might be halted. Officials constantly inquired as to how the various orders were being enforced throughout the country and as to the number of deaths. Even in Scotland, where it might be supposed that preventive measures would not be so carefully practiced, the same process went on. In July and September, 1564, for example, ships from Dantzig, where the plague flourished, were put in quarantine and their cargoes fumigated.

In 1574, a curious proclamation from the London mayor and aldermen, with the express purpose of avoiding the spread of the infection within the city, ordered all persons living in houses where the plague had visited within the preceding month or which should hereafter be affected not to come abroad into "any streate, market, shoppe, or open place of resort" within the city or its suburbs, until the plague had ceased in the said house "by the space of xx dayes at the least" except they carry in their hands openly one white rod at least two feet in length, upon pain of losing forty shillings. Also the clerk or sexton of every parish was commanded to set upon the door of every infected house a paper with the words, "Lord have mercy upon us," and to see to it that the same be not pulled down until the plague had ceased in the marked house by the space of one month. Finally no person having the plague should come abroad until the plague sore was fully healed.

In July, 1575, when the plague broke out at Bristol, ordinances required the taking of measures to avoid the plague, but they proved unavailing. Moreover, in the same year, when the government heard that the justices had left the town of Stamford to get along as best it might without making any provision for the poor, it deplored such a practice as not only bad for the town but also as likely to spread the infection abroad in the counties round about. In the following year the authorities of Kingston-upon-Hull complained that as the quarantine was not being strictly performed seamen brought the plague into the town. Because the infection chiefly affected one particular end of the town, special precautions were enforced there, porters handing in the provisions and standing guard day and night to prevent the sick from going out. At Northwick in Cheshire the linen of a plague-stricken household was thrown into the river to prevent its further use.

In London in 1578 the corporation appointed two "honest and discreet matrons" in each parish to search out and inspect every corpse in order to discover what had caused the death. The fact that these "matrons" often proved dishonest and indiscreet should not disparage the intent of the magistrates to halt the infection. Two nurses were also appointed for each parish to wait on the inhabitants of infected houses and to take care of the sick.

London, however, did no more than other important population centers. When Norwich was seriously menaced in 1579 some comprehensive orders appeared, inspired largely by the failure of some newcomers to keep their houses clean, by their practice of infecting the river with their washing, and also by "pouring out wash in their gutters, and not pouring water after it, whereby it resteth in the gutters and breedeth great infections." To reform such practices "a law was made, and a precept directed to them to redress the same." These people were commanded to take good regard

that their "necessaries be kept dry without washing, for the wash corrupteth and bringeth great infection, and use such cleansing of your houses, your clothes and bodies, and also such fumes and preservatives as the physicians shall advise you." They were told to kill all dogs within infected houses and suffer none at all to "wander and stray from house to house, but to be kept tied at home at their several houses," upon pain of imprisonment and fine.

At Yarmouth in the same year, liberty was given the fishermen to sell their products elsewhere at their pleasure, and tents and booths were erected outside the town so that they did not need to come inside "to make price of their herrings." Likewise the magistracy of Newcastle wrote the bailiffs of Yarmouth forbidding, on account of the grievous plague there, ships to come to Newcastle as usual for coals. At Ipswich in order the better to avoid the plague an ordinance provided "for supplying meat, drink and extraordinary diet to infected and necessitous persons" and required also "that every house so happening to be infected to have a load of weed" burned in it for airing purposes. At Canterbury a poor priest was employed during the thickest of the pestilence to kill the cats and dogs in the street, for which he received a set sum paid by the city.

Meanwhile, at London the plague continued and with it additional preventive measures. In 1580 the Privy Council forbade the bringing of goods from Paris, where there was infection; and five years later, the plague being at Bordeaux, the council prohibited commercial intercourse with that city for eight months. In 1582, when it appeared that the plague would again visit London, many precautions both old and new were enforced. People suffering from the plague themselves or having had it in their houses were, when they went out, to carry a white rod, one yard long, and persons from plague-stricken areas were ordered not to visit London. Furthermore, the Lord Mayor placed restrictions on burials, which so frequently were made in shallow graves and too close together.

At the same time the council informed the mayor that the Queen had ordered the courts to meet at Hertford and that he should "publicly prohibit any merchant, victualler, retailer, or other person within the city, whose houses either had been or then were touched with the infection," from sending into Hertford or places near it "any kind of merchandise, stuff, bedding, victual, or such like, upon pain of imprisonment:" In reply the mayor informed the council that "he had caused inquiries to be made of all victualling houses, which had been infected. A catalogue had been made with names of the dwellers, a description of the places, which had been prepared for printing, and set up as proclamations."

Likewise because of the prevalence of the plague in London, in 1582, the Oxford magistrates requested the mayor "to restrain all such your citizens from coming to the . . . fair, of whose houses and families there is any manifest token of that infection." In the following year, the Winchester corporation ruled "that if any house within this city shall happen to be infected with the plague," every person should keep his dog in the house. If any dog should be found at large, the beadle or any other person could kill it, and the owner should lose 6s. At Durham in 1589 the poorer people were removed into huts on the adjacent common in the hope of checking the infection, and at Plymouth in 1590 some "stufe was burned for avoiding the sickness." When at this time the Yarmouth authorities feared the possible return of the plague, women were appointed to visit the houses where any sickness or death should happen and report whether

or not the plague had been the cause and if such should prove to have been the case these houses, where the parties could not supply themselves, were to be supplied with all necessary things by a general collection. Every Saturday night lists were to be made of all who had died the previous week and of all infected houses. And it was further ordered that no one should resort to an ale-house except with a stranger and for especial business, and that all bedding and clothes coming out of infected houses should be carried outside the town to be aired, on pain of being burned.

When the heavy visitation of 1592–94 occurred, authorities everywhere took the most extraordinary precautions, for of all the epidemics in the reign of Elizabeth none was so grave in mortality or so far-reaching in its effects. The London council on September 7, 1592, ordered those having wells or pumps to pour, every morning before six o'clock and every evening after eight o'clock, at least ten buckets of water down the gutters, required the filth of the streets to be raked up, and commanded the constable of the precinct daily to make sure that the words, "Lord have mercy on us," remained on the door of an infected house for twenty-eight days, and if the same were defaced or taken away with the consent of the inhabitants of the house he should post a new paper and continue the segregation of the inhabitants for twenty-eight days from such defacing or taking away. Pavements were to be kept constantly in good repair to prevent the standing of water or accumulation of filth which might aid infection. Any one going on the streets with a sore running was to be imprisoned for twenty-eight days. An agreement was made with the College of Physicians that a certain and adequate number of physicians and surgeons be appointed and notified to attend the sick and that none but these deal with the infected. Warders were also appointed to watch outside the houses of infected people who did not observe the regulations and to arrest persons coming out of houses contrary to orders. Persons having had contact with the infection, either directly or indirectly, were to carry a red rod one yard long.

At about the same time the Privy Council issued a number of orders affecting other parts of the country. The soldiers levied in northern England were marched around London on their way to Southampton, in some cases levies being stopped altogether, and merchants were forbidden to resort to Portsmouth. Some prisons were even cleared of debtors. The council also ordered the mayor and sheriff of Dartmouth to forbid any one to visit London to buy goods during the plague and to put in prison those who disobeyed. Sir John Hawkins, the head of the Admiralty, took especial measures at the navy yards, and ended the making of starch at Deptford "because of the number of dogs used therein, which being a noisome kind of cattle, especially at this contagious time," were very apt to bring the infection.

The council then complained because the London magistrates refused to allow fires in the streets, since these, along with exploding gunpowder, had been found effective in purging the air, and they declared that if diligence were not used the Queen would suspend the sitting of the law courts. That the Queen's household might be better preserved, the council commanded that no one, except those who had good cause, repair to her court or within two miles of it. Nor should any one attending on the Queen repair to London or to places within two miles of the city without a special license in writing, upon pain of imprisonment by the Knight Marshal, who was to search for all vagabonds that haunted the court.

Early in 1593 when the plague returns, which for some time had been

diminishing, began to increase the council rebuked the mayor and aldermen for their negligence, either because they did not observe good orders for preventing the plague or because their orders themselves were insufficient. The magistrates therefore were commanded to take immediate notice of all houses infected or suspected of infection and to shut them up either by locks hanging outwardly on the doors or by a special watch on every house. The infected were to be prevented from mixing with the well and were to be taken care of while in isolation. The mayor and aldermen were further warned that if they continued to be careless, the Queen, in addition to the punishment she already meant to inflict on them, would remove Parliament from the city. Because of the increase of the plague the council prohibited all manner of concourse and public meetings, preaching and divine service excepted, at plays, bear-baiting, bowling and other assemblies, with the result that regular theater-playing ceased until June, 1594.

A little later the mayor was bidden to take extraordinary care to prevent the increase of the infection, and to keep the streets clean and sweet. All infected houses were to be shut up and watched, and the other orders already devised were to be obeyed. The justices of Middlesex likewise were charged to allow no dung or filth to breed infection. Meanwhile the council, keeping close watch over the general course of the plague, had to consider the great difficulty which the more remote parts of the country experienced in obtaining supplies for remedies. Consequently, it instructed shire towns to stock such supplies and appended a list of preventives and cures to its orders.

In May, 1593, the master of the Savoy Hospital was to forbear to receive any into the hospital because of the danger that the poor people repairing there daily may be infected with the plague, to the great danger of the inhabitants in general and especially to some of the council that dwell in those parts and are often occasioned to be at court and near the Queen. In the same month the Trinity term of the law courts was adjourned, owing to the increase of the plague. The following month, because the Queen intended to remain at Windsor for most of the summer, the Mayor of Windsor was to prevent people coming from any place where there was any infection from entering the town. Those persons who obstinately and undutifully refused to obey orders should first be admonished to move their families and then, if that failed, they were to be brought before the council to answer for their contempt.

At the end of June, the customary great feasts made by the City Companies were curtailed and the money saved was to be converted to the relief of the infected. Because of continued negligence in the matter of allowing infected houses and shops to remain open or of compelling them to be shut only a short time, the mayor and aldermen were warned that, unless reform took place, the Queen would be moved to commit the government of the city to others. A few days later the mayor requested that, because of the great discommodity that would attend the prohibition of St. Bartholomew's Fair, the proclamation of the council forbidding that fair might be stayed until it were seen whether "by God's goodness and the Lord Mayor's careful endeavor the increase of sickness be allayed." At the same time he suggested that since the white crosses painted on those houses visited by the plague were easily wiped away, red crosses be nailed on the doors and a watch kept to prevent those within from going abroad. Because "God's goodness" and the mayor's "careful endeavor" did not prove sufficiently effective, the fairs usually held in the months of July, August and September were abandoned, the Queen pre-

ferring the preservation of her subjects to private benefit.

Due also to this increase in the plague the council informed the mayor and the aldermen that although the plague proceeded from God as a due punishment of wickedness all possible means ought to be used to prevent the spread of the infection. If, it was said, as good care were used in keeping the orders as in making them, especially in restraining the infected from the sound, it would with God's help do great good. It was recalled that at Kingston, upon the first infection, they caused a house to be made in the fields distant from the town where the infected might be kept apart and provided for all things convenient for their sustenance and care; and the same should be done in London. Mention was also made of a little book set forth in the time of the great plague and last year printed again which contained divers good precepts and orders and which might be recommended by the minister of every parish to all housekeepers. Finally, on this occasion, the council required the suppression of all who sold old apparel, a trade in no wise to be suffered in time of infection.

Perhaps because of these constant exhortations the mayor and alderman issued a most elaborate set of orders for removing such enormities as not only continued but increased the plague and disorders of the city, and for providing for the poor and setting them to work. Aldermen or their deputies were to charge churchwardens, constables, parish clerks and beadles to inquire what houses were infected; they were also to visit the ward often to see orders observed, especially touching cleanness in the streets, to appoint surveyors monthly in every parish, to see that certificate be made to them concerning the infected houses, to give charge to all teachers of children that they permit no children to come to their schools from infected houses, especially until such houses have been free for twenty-eight days, and that none keep a greater number than their rooms shall be thought fit to contain. Surveyors were to see that the orders for the sick were executed daily and diligently, and they were to appoint purveyors of necessaries for infected houses and to deliver them reed rods to carry and see that none other resort to these houses. Constables every day were to bring notice in writing to the aldermen what houses were infected. The constable and the churchwarden were to have in readiness women to be providers and deliverers of necessaries to infected houses and to attend the infected persons; these were to bear reed wands, so that the sick might be kept from the whole, as much as possible. The constable and the beadle were to inquire what houses were infected and to see daily that papers remained upon doors twenty-eight days or to place new ones. Clerks and sextons were to understand what houses were infected, to see bills set upon the doors of houses infected, and to suffer no corpses infected to be buried or remain in the church during prayer or sermon, and to keep children from coming near them. Scavengers and rakers were to see the streets made clean every day saving Sunday and the soil to be carried away, and to warn all inhabitants, against their houses to keep gutters clear from filth that the water might have passage. Every official was to kill dogs and other animals loose upon the streets or lose his place.

Not only, however, were various responsibilities placed on officials, but householders were likewise to aid in checking the infection. Houses having some sick though none died, or from which some sick had been removed, were infected houses, and were to be shut up for a month, and the whole family to remain twenty-eight days and to keep shut the lower rooms for the like space. One member was to go out for provisions; no

clothes were to be hanged in the street. As earlier, those having wells were to pour ten buckets full into the streets twice a day, every evening at eight o'clock the streets and gutters were to be made clean, the water not swept out of the gutter nor the streets made over-wet but sprinkled. The houses infected and the things in them were to be well aired, and no clothes or things about the infected persons were to be given away or sold but were to be destroyed or sufficiently purified. Owners of houses infected might depart within the month to their houses in the country or to any other house in the city without being shut up, so that they abstained from returning to the city, or from going out of the house in the city, for a month. None were to allow dogs out unled or within, howling and disturbing neighbors. No one was to visit infected houses but such as belonged to the house or was licensed to do service. Dunghills and bearhouses in the street were forbidden. Persons consenting to the pulling down of the words, "Lord have mercy on us," were to be restrained double time and the "taker away" was to be imprisoned for eight days. Meetings were prohibited.

The magistrates also appointed two viewers of dead bodies and two viewers of the suspected sick. These viewers were required to report to the constable, who in turn reported to the clerk, who went to the chief of clerks, all upon pain of imprisonment. False reports by the viewers called for standing in the pillory. A loss of pension was suffered by those who refused to do their duty. Diligent care was to be had to the mending of the pavements, principal pavers were appointed to survey the needs, especially in gutters, and the dwellers against such were forced to mend the breaks. If it was feared that the plague increase, plays might be restrained. Skilful and learned physicians and surgeons were to be provided to minister to the sick. The vagrant, masterless and poor people were to be sent to St. Thomas or St. Bartholomew's hospital, there to be first cured and made clean, and afterwards those not of the city to be sent away according to the statute, and the others to be set to work, in such trades as are least used by the inhabitants of the city, for the getting rid of the vagrants and loiterers who spread the infection. All masterless men who lived idly in the city without any lawful calling, frequenting places of common assemblies, as theaters, gaming-houses, cockpits, bowling alleys and such other places, might be banished from the city according to the laws in that case provided. All these orders the aldermen and their deputies were every one in their place to see performed, both in themselves and others, and in cases of doubt to yield their opinions and give directions.

Meanwhile, throughout other parts of the country preventive measures did not fail to make an appearance. During the Stourbridge Fair, the gates of the colleges at Cambridge were closed and no students were permitted to attend the fair. At Winchester, the visitation being dreaded, the authorities ordered the strictest inquiry to be made about foreign persons coming from any infected place, each of the town's six gates having a warden on duty. Shortly afterward, at Newcastle, although it had been customary to let the colliers out of the city early in the morning for their work, during the pestilence the magistrates put a stop to their going and coming; the colliers in the time of plague had to dwell beyond the walls. Moreover, men were warned to keep in their dogs and swine, and ducks were not allowed in the public pond because they too were suspect as plague carriers.

As the plague continued into 1594, it was observed that great inconveniences grew daily by the erecting of new tenements within London, Westminster and the suburbs, which much caused the infec-

tion by reason of the multitude of poor people that inhabited them, many dwelling together in one small space. The preceding Parliament had sought the reformation of these inconveniences, but now, seeing that the greatest number of plague deaths occurred in those houses pestered with inmates, the mayor and the aldermen were commanded to order that no new persons should be admitted to those tenements in the room of those that had died. A final precaution of 1594 that may be mentioned was the building of a pesthouse at London, but unfortunately its accommodations were totally inadequate and the city did not see fit to enlarge these all too limited facilities in the succeeding seventy years.

During the remainder of the sixteenth century there was no such wide-spread epidemic as characterized the years 1592–94, yet in various parts of England men continued to die of the pest and various precautions still operated. In 1596 the council sent letters to the justices of Middlesex and Surrey to restrain the players from showing any plays or interludes in the usual places about the city of London, fearing lest assemblies of people increase the contagion. At the election of the magistrates of Newcastle in the autumn of 1597 "rushes were spread thickly about the floors of the hospital and the sweet-scented herbs . . . . more lavishly strewn than was wont. The ceremonies ended, the burgesses, not to be balked of their accustomed feast of geese, made it to proceed without interruption, there being burnt during the whole time certain perfumes whose vapours, penetrating every nook and corner of the place, lulled the festive crew into a belief of temporary security." At Penrith in northern England during the visitation of 1598 outsiders refused to bring their commodities into the town market; the inhabitants therefore were under the necessity of meeting them halfway where a kind of quarantine was performed. No outsider touched the money used by the townpeople until it had been put in water from which it was extracted without the fingers touching it.

Before concluding this sketch of plague medicine it may be briefly emphasized that in contrast to the following century the plague of the sixteenth century did not stimulate any great body of pamphlet literature, and thus we are deprived of that immensely informing body of sources which prominently featured later visitations. Yet a few tracts did appear, to reveal that, whereas officials looked mainly to prevention and restriction, doctors were perhaps most inclined to concentrate on cures. These tracts contained a mixture of popular prejudice that bordered on folklore nostrums and at the same time a considerable amount of what modern health officials would describe as common sense. If they do not add a great deal to the thesis presented here they do round out the story of sixteenth century plague medicine.

In 1586 Thomas Cogan published "The Haven of Health: chiefly made for the comfort of students, and consequently for all those that have a care of their health, amplified uppon fine wordes of Hippocrates, written Epid. 6. labour, meate, drinke, sleepe, Venus." This tract, reprinted in 1589, came out in a second edition in 1596 and was reprinted in 1605 and in 1636. Cogan, a "Maister of Artes and Bachelor of Phisicke," advised that in order to escape the pestilence people should always take in their hands "an orange, or a posie of rew, or mint, or balme." He emphasized that against nature "Phisick can not prevayle; when nature will no longer worke, then farewell phisick. . . . The phisician may do his endeavour, but the successe is in God." Moreover, Cogan insisted that "among all things that purifie the ayre, either within the house or without, none is better than fire."

Some years later Simon Kellaway

wrote "A Defensative Against the Plague," containing two parts, the first how to preserve from the plague, the second how to treat those who were infected. The causes of the plague were great and unnatural heat and dryness or by contrast great rain and inundations of water, great store of rotten and stinking bodies lying unburied which corrupted the air so that corn, fruits, herbs and waters were infected, dunghills, filthy and standing pools of water, and the thrusting a great number of people into a close room, as in ships, common gaols and in narrow lanes and streets. But for the most part it came from clothes and the like that had been used about some infected body; and it might also come from dogs, cats, swine and weasels.

Certain signs foreshadowed the plague, as when the spring time was cold, cloudy and dry, the harvest stormy and tempestuous, with mornings and evenings very cold and at noon extreme heat. Other prophetic signs were comets, many frogs at the beginning of harvest and toads with long tails creeping on the earth, all of which showed the air to be corrupt. Also when young children flocked together in companies, and, feigning one of their members to be dead, solemnized the burying in mournful sort, the plague was likely to appear.

The plague threatening, the magistrates should command that no stinking dunghills be allowed near the city and should keep the streets sprinkled and cleansed from all filthy things, especially in hot weather. Where the infection was entered they should order fires to be made in the streets every morning and evening, wherein should be burnt frankincense, pitch or some other sweet thing. They of course should suffer no dogs, cats or pigs to run about the streets and see to it that all excrements and filthy things voided from the infected places be not cast into streets or into sewers. No surgeons or barbers that let blood should cast it into the streets or rivers, nor should vaults or privies be emptied therein, for that was a most dangerous thing. All innkeepers should clean their stables every day and cause the filth and dung therein to be carried out of the city, for by suffering it in their houses as some used to do a whole week or fortnight, it putrefied so that when it was removed there was such a stink as was able to infect the whole street. Magistrates should command that no hemp or flax be kept in water near the city or town, for that will cause a very dangerous and infectious savor. Finally, they were to take special care that good and wholesome victuals and corn be sold in the markets, and to provide that no want thereof shall be in the city, for there was nothing that more increases the plague than want and scarcity of necessary food. The remainder of the book contained receipts for perfumes, pomanders, preservatives, purges, cataplasms, powders, unguents, and the like for the various occasions of the plague, with directions for its prevention and cure.

Shortly afterward there appeared a little book, "Present Remedies against the Plague," reprinted again in 1603, which showed sundry preservatives through the use of wholesome fumes, drinks, vomits and other "inward receits" and also the "perfect cure" of those already infected. The author, "a learned Physition," writing for the better health of his country, gave remedies "for ayring your roomes," roots "to smell to" and to "taste or chewe in the mouth," and the medicines that would "procure sweat" or a "special vomit." He also advised people to keep their houses, streets, yards, sinks and ditches sweet and clean from all standing puddles, dunghills and corrupt moistures, and not let dogs, "which be a most apt cattle" to carry the infection, come running into the house. In particular, he declared that rooms should

be aired with charcoal fires, made in stone pans or chafing dishes, and not in chimneys. As for other remedies, he recommended a favored preservative, which involved chewing the root of angelica, setwall, gentian, valerian or cinnamon, and also the eating of a toast of bread, sprinkled with red rose vinegar, buttered and powdered with cinnamon, and eaten fasting, and finally the drinking of rue, wormwood, and scabias, steeped in ale a whole night and drunk fasting every morning, or the water of *carduus benedictus*, or *angelica*, mixed with *mithradatum*.

These remedies, however, should not be considered the full measure of plague medicine, for by the end of the sixteenth century the plague was oftenest regarded neither as symptomatic of God's wrath nor as an incomprehensible visitation to be propitiated through the agencies of folklore but rather, especially by those in a position to make their attitude felt, as a phenomenon which could be avoided or at least regulated and restricted. The abundance of official orders constitutes the best evidence that in the matter of the plague the sixteenth century was not unaware of its medical problems. These ordinances answer the contention that the plague was met only by superstitious incantations, weird combinations of herbs, toads and excreta, or the confession that nothing could be done about it. While sanitary arrangements were far from perfect, a casual stroll through a modern community will indicate that present-day standards of judgment are quite insecure. The miasmic odors of open sewers, the exposed garbage dumps, the endearing caresses heaped upon household pets which have swept up the city streets in their passage, the foul air and a dozen other conditions reveal no utopia of sanitation in the twentieth century. In any case it is enough for us to appreciate that the authorities of sixteenth century England made persistent and intelligent efforts to halt a scourge that carried with it such diverse and far-reaching effects as did the plague.

WORM PARASITISM IN DOMESTIC ANIMALS

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Some General Considerations of Helminth Parasitism

Parasitism is an ancient but not an honorable partnership between two species of animals, one of the partners, the parasite, getting all that he can from and contributing nothing but grief to the other partner, the host. Since parasitism due to worms is wide-spread in all groups of vertebrates, it may be assumed that the association between a worm parasite and a host is a biological partnership that, in most cases, is not fraught with too great a hazard for the host under natural conditions as opposed to man-made artificial conditions.

Under natural conditions the parasite is in a rather precarious situation so far as self-perpetuation is concerned. Parasites perpetuate themselves through eggs or larvae which issue from eggs. Once they are eliminated from the host's body the eggs or larvae may be destroyed by inimical environmental influences, such as unfavorable temperature, strong sunlight and drying, before they have undergone any development or while they are developing. If the eggs or larvae escape these and other destructive influences, they may not be taken up by a host in which they can complete their development or they may not be taken up by any host, in which case they succumb sooner or later. In the case of parasites which require an intermediate host for the completion of the life cycle, the chances of survival become increasingly smaller because the egg or larva must reach the proper intermediate host, which, in turn, must establish the right sort of connection with the proper final or definitive host. Only the worm parasites that are transmitted by blood-sucking arthropods have overcome to a large extent the risks attendant upon the completion of the life cycle. In short, the life of a parasite may be a happy one while it lasts, but the continuity of any species of parasite through centuries in which parasitism has existed might have involved at least occasional risks of extinction for some species of parasites. Considering the great hazards involved in the completion of the life cycle, a high intensity of infestation with parasitic worms is largely the result of a restricted range of the host.

Assuming that under natural conditions species of parasites have not become extinct, as a rule, one explanation for their persistence is probably their extraordinary reproductive capacity. It is doubtful whether any other ecological group of animals has a greater reproductive capacity than that exhibited by the parasitic worms. The latter live in a sheltered environment, rich in food supply. The energy which free-living animals expend in satisfying the fundamental instinct of self-preservation by securing food and in escaping annihilation by enemies and by the destructive forces of nature, is thus available to the parasite to be utilized for some other purpose. That parasites utilize much of their energy in reproduction is evident even to the novice in parasitology. The abundant reproductive capacity of parasites thus compensates to a large extent for the uncertainty that the eggs or larvae of a particular species will reach the proper host at the proper time, and virtually assures at least the perpetuation of the hundreds of species of worms which parasitize the animals which man raises for pleasure or profit.

Under conditions which can not be regarded as natural, such as those involving the customary animal husbandry operations, even the slightest risk of extinction attendant upon the parasitic mode of life has been largely, if not entirely eliminated. In fact, the husbandman, by restricting the range of the host animals in order to feed them and otherwise care for them, has created an ideal situation for the perpetuation of parasites. He has become a breeder not only of live stock but inadvertently also of live-stock parasites. By confining his animals to increasingly smaller areas, the stockman has transformed the host-parasite relationship from what might have been at one time a more or less normal biological relationship into a relationship which has become pathogenic to the host because of the high intensity of parasitic infestation of meat food and other animals raised under farm conditions.

One of the great surprises which the parasitologist receives on his first visit to the tropics is the general lack of abundance of parasitic worms in domestic animals other than household animals. The tropical environment, with its equable climate and usual abundance of moisture, offers, theoretically at least, ideal conditions for a thriving parasitism. That tropical conditions are favorable to the perpetuation of worm parasites is evident from the fact that the incidence of such parasites in human beings and household animals, such as dogs and cats, is high in the tropics. Therefore, the general low incidence and low intensity of parasitism in live stock in the tropics must be accounted for on a basis other than environmental. Actually, the relative scarcity of live-stock parasites in the tropics is due to the relative scarcity of live stock. With the increase in the numbers of live stock and the introduction of customary animal husbandry practices, parasitism will assume increasing importance in the tropics, this being evident already by occasional reports of intense and even fatal parasitic diseases of horses, ruminants and hogs in tropical countries, the general clinical picture of these parasitic diseases in the tropics being essentially that observed in temperate zones.

Assuming, therefore, that the high incidence and high intensity of parasites observed in live stock in practically all sections of the United States has resulted for the most part from a gradual restriction of range in the face of an increasing live-stock population and from the use of more or less permanent pastures which have become saturated with the eggs and larvae of parasitic worms, it is not surprising that parasitism in live stock has become an economic problem of great magnitude and importance in this country. That this problem must be kept in mind and taken into consideration in all attempts to formulate sound husbandry practices will become evident from the following brief review of the essential facts regarding some of the more important internal parasites of live stock in this country.

Parasites of Swine

Swine harbor many species of internal parasites, of which the following are among the most injurious:

Intestinal roundworms or ascarids: The large intestinal roundworm or ascarid occurs as an adult in the small intestine, where it attains a length of about an ordinary lead pencil. Swine become infested with this parasite as a result of swallowing the infective eggs of the worms; the eggs are eliminated with the droppings of infested swine and reach the infective stage in about three weeks under favorable conditions. One of the most interesting discoveries in connection with these roundworms came to light about twenty years ago. Up to that time it was generally believed

by parasitologists that the swine roundworm egg hatched in the stomach or intestine of its host, and that the young worm which issued from the egg developed to maturity without straying from the lumen of the gut. In 1916 it was shown for the first time that, after hatching, the ascarid larva penetrated the wall of the intestine, migrated with the blood stream to the liver and thence to the lungs and finally returned to the intestine by migrating along the bronchioles, bronchi, trachea, pharynx, esophagus and stomach. In the course of these investigations it was noted that if many larvae went through the lungs at the same time they produced symptoms and lesions of pneumonia. These findings placed the ascarid in the category of a serious pathogen, endowed with far greater capacity of doing harm than had ever before been suspected. On getting into the intestine the second time, the ascarid larvae settle down and develop to maturity in the course of about two months. The mature females produce astonishingly large numbers of eggs which pollute the pastures in which the infested host animals are kept, thus paving the way for infection of young pigs which are kept on such pastures.

It has been shown that one female ascarid may discharge about one quarter of a million eggs in a single day. If the egg-laying period of a female should last one hundred days, a pig harboring about twenty-five female ascarids would discharge during this period about 625,000,000 eggs. In the light of such figures it is not surprising that pigs raised on permanent pastures acquire exceedingly heavy ascarid infestations at a period of life when they lack the ability to successfully cope with such infestations. The net result is a serious setback, from which complete recovery is not made, or death, in cases of extremely heavy infestation.

Kidney worms: The swine kidney worm is more or less unique among parasites in that it has no communication with the alimentary canal, its eggs being discharged to the outside with the urine. The adult worms occur in burrows in the kidney fat and in the kidney itself; the worms in the kidney fat establish channels to the ureter, which they puncture, thus affording an outlet for the eggs to the outside.

Kidney worm eggs develop on the ground rapidly and hatch in a day or two under favorable conditions. In about five days or longer, depending on the temperature of the environment, the larvae attain the infective stage, following two molts. The infective larvae can enter the bodies of swine either through the skin or through the mouth; however, regardless of the portal of entry, the larvae migrate to the liver, and those that extricate themselves from this organ do so by perforating the liver capsule. The worms which fail to escape from the liver become encapsulated. From the surface of the liver the incompletely grown worms migrate to the perirenal fat, which they perforate rather easily. As already stated, some of the worms enter the kidney. The entire cycle in the host proceeds rather slowly, about six months being necessary, as a rule, for the attainment of sexual maturity.

Nodular worms: Nodular worms occur as adults free in the lumen of the large intestine. The eggs of these worms are discharged with the manure of infested swine. The eggs hatch on pastures and the larvae develop much in the same way as do kidney worm larvae. Infestation results solely from swallowing the infective larvae with contaminated feed or water. Hogs which root among trash and debris are likely to pick up heavy infestations with nodular worms, since the larvae seek shelter among such debris, where they survive for relatively long periods.

Lungworms: Lungworms are acquired by hogs as a result of swallowing infested earthworms which are brought to the surface by rooting. Earthworms in turn acquire this infestation as a result of feeding on swine manure. Hogs infested with lungworms may eliminate lungworm eggs over a period of several months. In an experimental infection, involving the feeding of only 500 lungworm larvae, isolated from earthworms, the writer estimated an output of over 3,000,000 lungworm eggs with one day's droppings at the height of egg production. An infestation of the sort produced by the writer experimentally can not by any means be regarded as a heavy infestation. A single infested earthworm collected by the writer in a hog lot was found to harbor approximately 2,000 larvae. A hog which swallows a single earthworm so infested, and a single rooting expedition might reward the rooter with many earthworms, would acquire a sizable infestation, sufficient to produce in the lungs extensive pneumonic areas.

Thorny-headed worms: The thorny-headed worm of swine, like the lungworm, also has a complicated life cycle, in the course of which the eggs of the parasite, eliminated with the hog's droppings, develop in May-beetle larvae if the latter feed on swine manure. Swine become infested as a result of swallowing infested May-beetle larvae.

Stomach worms: Among the parasites which contribute to a large extent to the picture of unthriftiness in swine are the three species of stomach worms, of which one species, the red stomach worm, has a direct life history, similar in some respects to the life history of nodular worms; the remaining two species of swine stomach worms have indirect life histories, species of dung beetles serving as intermediate hosts. The beetles pick up the infestation as a result of swallowing the eggs with swine manure; swine become infested by swallowing infested beetles. The stomach worms that are transmitted by dung beetles produce marked pathological changes in the stomach wall, characterized by a conspicuous catarrhal inflammation.

Controlling Swine Parasites

From this brief review of the mode of transmission of some of the more common parasites of swine, it is evident that the parasites which have been discussed, excluding the kidney worm, are transmitted either directly through the manure or indirectly through intermediate hosts. In either case the manure is the ultimate source of the infestation, and control measures must be based to a large extent on manure disposal or on some other procedure which will protect pigs from contamination with manure of older hogs.

Because of the conditions under which swine are usually raised, parasitism has become a serious problem in swine husbandry operations. Much of the stunting of pigs, respiratory diseases early in life, loss in condition, general unthriftiness and condemnation under meat inspection procedure are due to parasitic infestation. While these losses can not be estimated accurately in terms of dollars and cents, the aggregate losses, considering the various kinds of swine parasites definitely known to be injurious, must run into several million dollars annually.

Several years ago investigators of the Federal Bureau of Animal Industry determined that the losses from kidney worms in a single relatively small packing house located in one of the southern states amounted to about \$50,000 a year. Practically all the livers, kidneys and kidney fat of hogs raised in infested areas and killed at that abattoir were condemned, and the loins of about 10 per cent. of the hogs had to be extensively trimmed under federal meat inspection

procedure. In the same plant it was estimated at one time that condemnation of the large intestine of hogs because of lesions due to a certain species of nodular worm would show an annual loss of about $25,000, this estimate being based on figures available at the time that the calculation was made. Considering the fact that more than one third of the hogs which are raised in the United States are raised in the South and that the two species of worms above mentioned as responsible for the losses under meat inspection procedure are more prevalent in the South than elsewhere, the total losses to the live-stock and meat industries of the South from these parasites alone must reach a rather significant figure.

In addition to the loss under meat inspection procedure, it is important to consider the direct loss to the farmer. The latter loss is practically impossible to estimate; that it represents a tangible loss in the form of stunted growth and unthriftiness is evident from the following considerations.

About 10 years ago the Federal Bureau of Animal Industry initiated a research project in the South, the purpose of which was to investigate the extent and degree of swine parasites and to develop practical control measures, with special reference to kidney worms. This project involved a searching investigation on the life history of the swine kidney worm, a study of the resistance of the eggs and the larvae of this parasite to various environmental influences, a study of the distribution of the larvae on pastures, including a consideration of their duration of life under various conditions and similar more or less technical problems.

As a result of these investigations and in conformity with the facts elucidated, there was formulated a method of control, involving for the most part modifications in swine husbandry practices of a sort which would subject kidney worm eggs and larvae to the destructive influences of sunlight and drying. The practical arrangements, developed under farm conditions, involved a bare strip at one end of the pasture, the feeding pen for the sow, the creep for the pigs, the watering facilities and the shelter houses being placed on this bare area. Provision was made also for bare narrow strips along the fences, wherever practical. Under these arrangements most of the urine voided by the hogs reached the bare ground where the kidney worm eggs that are eliminated with the urine were exposed to the lethal action of sunlight and drying. Under these arrangements, which were coupled with sanitation in the broad sense, precluding the accumulation on the pasture of corncobs and husks and other litter which afforded a haven to kidney worm eggs and larvae, it was possible to control kidney worm infestation to a large extent. The success attending the practice of the precautions mentioned varied to a large extent with the degree of adherence to details of sanitation, with the result that a strict adherence to these details yielded practically 100 per cent. results. These procedures are now being adopted not only in the region where they were shown to be practical and profitable, but also in other sections of the South.

The losses among swine due to stunting and unthriftiness as well as to the losses because of kidney worm lesions under meat inspection procedure have been practically eliminated in those cases in which the sanitary procedures were followed. Moreover, these procedures were found to be effective in controlling ascarids and lungworms as well as kidney worms and they were at least partially effective in controlling nodular worms.

In brief, the problem of swine parasite control, reduced to simple terms, involves sanitary arrangements of a sort

that will protect the pigs from acquiring the species of parasites harbored by the sows. Since the pigs must remain with the sow during the suckling period when their susceptibility to parasites is at its height, any practical arrangements that tend to destroy the eggs and larvae of parasites on pastures will reduce the potential and actual infestation and thus help to tide over the pigs during their most critical period in life.

Parasites of Horses

Horses are among the most heavily parasitized domestic animals as regards the number of species harbored and as regards the actual number of worms present in individual animals. Individual horses that are kept under sanitary conditions with regard to housing and fed properly may harbor several hundred worms, even when these host animals have but little access to pastures. Horses that are not properly cared for are veritable menageries of helminths and harbor thousands of worms, located for the most part in the digestive tract, but occurring also in other parts of the body, including practically all the thoracic and abdominal viscera, the blood system, in fact, practically all organs and tissues of the body. In the discussion which follows only the most important parasites of the alimentary canal will be considered.

Stomach worms: Three species of horse stomach worms of common occurrence in this country are transmitted by various species of flies, including biting as well as non-biting flies, the flies becoming infested in the maggot stage while feeding on horse manure. The adult flies infect horses as a result of feeding on the moisture of the lips and nose of these animals, the heat of the horse's body stimulating the larvae to escape from the flies onto the lips or into the nose. Since these larvae are very active, they probably wriggle into the mouth and nostrils, and thus reach the stomach, where they develop to maturity. The stomach worms attach to the wall of the stomach, and one of the three species, *Habronema megastoma,* produces conspicuous tumors on the stomach wall, the worms being located within these tumors.

Ascarids: The horse ascarid, about as well and as unfavorably known as the swine ascarid, has a life history essentially similar to that of its first cousin. This life history has already been outlined and will not be repeated again. In experimental infections of foals with ascarids, the host animals showed rise in temperature and coughed considerably. That these symptoms were due to the migration of ascarid larvae through the lungs was clearly demonstrated in a post-mortem examination of the experimentally infested foals; the larvae of ascarids were actually discovered in the trachea, this location corresponding to the route which the larvae follow on their return journey to the intestine.

Strongyles: The worms in horses which are best known to veterinarians and farmers, because of the injuries which they inflict, are the strongyles, of which there are about sixty known species, the habitat of these worms being the cecum, ventral and dorsal colon. Some of the strongyles are well known because of their size, their more or less reddish color and their firm attachment to the wall of the gut. Other strongyles, because of their smaller size, inconspicuous color and the fact that they are not found attached to the wall of the gut during necropsy, are perhaps not so well known. However, all the strongyles of the horse are potentially pathogenic and several species have an established reputation for being veritable racketeers. The worst offenders are not merely content to rob the host of his precious life blood, but they injure him extensively by invading many vital organs, including the liver, spleen and kidneys; one

species, *Strongylus vulgaris,* is a serious pathogen and is responsible for the production of aneurisms of the anterior mesenteric artery. These aneurisms interfere with the blood supply to the gut and are responsible for colics which reduce the working efficiency of horses.

Strongyles have simple life histories; the eggs which are eliminated with the horse's droppings develop on pastures in a day or two under favorable conditions, and the newly hatched larvae become infective three or four days later under equally favorable conditions. The larvae are very resistant, however, to adverse environmental influences, being capable of surviving for long periods under the influence of prolonged drying and severe sub-zero weather.

Horses acquire an infestation with strongyles as a result of swallowing the infective larvae with green feed, dry feed or as a result of drinking water contaminated with such larvae. Many of the details of the subsequent migration of the larvae in the body of the host have not been ascertained. It is certain, however, that some species of strongyles wander extensively in the horse's body and get into situations from which they can not extricate themselves in order to resume their migration to the large intestine. As a result of these straying habits, the larvae leave behind a trail of lesions to vital organs, these injuries having a more or less pronounced effect on the host.

Controlling Worms in Horses

It has been shown in a series of controlled experiments with mules in Louisiana that the administration of anthelmintics known to be effective in removing strongyles from horses was followed by a restoration of normal working capacity in animals which had been more or less incapacitated for some time prior to treatment. A series of similarly incapacitated mules, not treated for the removal of worms, continued to suffer from colic and remained incapable of working at a normal rate. Graham in Illinois had remarkable success in restoring to usefulness a horse which had been condemned by the Army, by resorting to anthelmintic medication. This animal not only gained weight, showed a steady increase in hemaglobin content and red blood cells, but underwent an amazing transformation from a weak, emaciated, decrepit animal, with a rough coat, tucked-in flanks and sunken eyes, to a spirited mount that any rider would be glad to possess. These are but a few instances of the effect of parasites and especially of strongyles on horses.

In view of great resistance of the larvae of horse strongyles to inimical environmental influences, the control of horse parasites by sanitation alone is not practical and is usually unsuccessful. Horse parasite control must involve a combination of stable and pasture sanitation, pasture rotation as often as available pastures permit, and periodic treatment for worm removal.

Stable sanitation is largely a matter of proper disposal of manure in order to remove potential infective material. The spreading of horse manure on pastures to which horses might have access even a year or two later is equivalent in its results to an intentional dissemination of infective larvae. Pasture sanitation presents far greater difficulties than stable sanitation. The removal of manure from pastures is actually in progress, however, on certain farms devoted to the breeding of Thoroughbreds. Such procedure is too expensive and too impractical, however, for the average farmer and can be recommended only in special cases.

The Zoological Division of the Bureau of Animal Industry has developed a manure box for temporary storing and rendering a horse manure free of live worm eggs and larvae. The box has

double walls and a double floor and is provided with a well-fitting lid. Work which was conducted by the writer in collaboration with some of his associates in the Bureau of Animal Industry has shown that after about two weeks' storage, the manure is practically free of worm eggs and larvae, the few that survive in cold pockets in the box being negligible in comparison with the thousands that perish. The destruction of life in the eggs and larvae is brought about by the self-heating which horse manure undergoes, the temperatures attained in the process of self-heating being more than adequate to kill the eggs and larvae.

In view of the rather long storage period required for the accomplishment of the desired results, the Zoological Division has been experimenting with the sterilization of manure, so far as parasites are concerned, by means of live steam at approximately 15 pounds pressure. These experiments are still in progress, but the indications are that the manure subjected to steam as mentioned can be rendered helminthologically sterile in the course of an hour or so.

The subject of rotation of stock will be discussed in connection with the parasites of domestic ruminants. Rotation of pastures, so far as controlling horse parasites is concerned, is of rather limited value, considering the longevity of horse strongyle larvae even under adverse environmental conditions. Treatment for worm removal offers a practical solution to the problem of horse parasite control. Removal of worms affords the infested animals relief from the drain of the infestation and cuts down the supply of worm eggs at the source. Treatment for worm removal is, therefore, a part of prophylaxis.

Bots: Bots are the maggots of certain flies (Gastrophilidae) which occur in the gastro-intestinal tract of equines. They are included in this discussion solely for the purpose of rounding out the picture of gastro-intestinal parasitism in horses.

In recent years the control of bots in horses has attracted considerable attention, perhaps because the average farmer and horseman knows more about bots than about strongyles. Bots injure the stomach and duodenal wall to which they are attached and contribute to the picture of unthriftiness that is so commonly associated with parasitic infestation. Moreover, the adult botflies annoy horses and are responsible for runaways.

Briefly, bots develop from eggs deposited on and glued to the hair, each species of bot having its preference for a certain part of the body on which the eggs are deposited. The common bot, which occurs in all parts of the country, glues its eggs usually to the hair of the legs; the chin bot glues its eggs to hair of the jaw, and the nose bot glues its eggs to hair on the lips. The eggs of the common bot hatch under the influence of moisture and heat, the horse supplying the moisture and heat while licking itself and the larvae being carried to the mouth by the tongue. The eggs of the chin bot hatch without moisture, the larvae crawling into the mouth after hatching. The manner of the hatching of the eggs of the nose bot has not been ascertained. It has been shown recently that once the newly hatched bots reach the mouth, the larvae penetrate into the mucosa of the tongue and cheeks and that, in the case of the common bot, the larvae do not reach the stomach until about twenty-one to twenty-eight days after they have been taken into the mouth.

On the basis of these findings the rational procedure with regard to treatment, when only one treatment is given in the course of a year, is to administer carbon bisulfide one month after the first killing frost. Presumably the adult flies are killed by the frost, and by deferring

treatment for a whole month after the killing frost, the larvae that are already present in the mucosa of the tongue and cheeks will have reached the stomach. Thus, the maximum results can be attained by a single treatment if the aforementioned recommendation is followed.

Parasites in Ruminants

Cattle, sheep and goats are seriously affected by worm parasites. Sheep, in particular, suffer severely from parasitic infestation, the latter being the major drawback to successful sheep husbandry. The control of parasites of domesticated ruminants thus constitutes a problem of major importance to the owners of these animals.

Stomach worms: It is hardly necessary to emphasize the pathogenicity of the stomach worm to sheep. In nearly all sections of the United States, this worm is the chief obstacle to successful sheep raising. A slight initial infestation in several sheep may produce heavy infestations in large flocks in the course of a single season. This is brought about as follows: The eggs of the parasite are eliminated with the feces of the host; during the summer months, the eggs hatch in a day or so. The larvae undergo their preparasitic development on pastures in a few days. The infective larvae climb up grass stalks and blades, when sufficient moisture is present to enable them to move in the films which settle on the grass. During rains, fogs and dews, the larvae become very active in their upward migrations, and this brings them into favorable situations to be swallowed by sheep while the latter are grazing. In about three weeks after the larvae are swallowed, the worms attain fertile maturity and the females begin to deposit eggs, which are eliminated with the sheep's feces, thus starting the life cycle of the parasite once more.

As an example of the tremendous fertility of the stomach worm and of the rapidity with which an infestation with this parasite can be developed to enormous proportions, as judged by the quantity of eggs which the worms produce, the following case, reported by Stoll, may be cited. Twin lambs, about eleven weeks old, raised by hand since birth, kept under conditions which precluded infestation with stomach worms and other parasites and actually found to be free from parasites so far as negative findings on microscopic inspection of the feces afford evidence, were placed on a pasture on which no sheep or other ruminant had been kept for at least two years and which no sheep had traversed during that period. It is reasonably safe to assume that this pasture was free from larvae of stomach worms. One of the lambs was given forty-five stomach worm larvae by mouth. This lamb began to discharge stomach worm eggs nineteen days after the larvae had been fed, the egg output increasing gradually and reaching a peak of 13,600 eggs per gram of feces about twelve and a half weeks after the infection was started. The second lamb, to which no larvae were fed and which presumably acquired its infestation from the larvae which hatched from eggs discharged by the first lamb, began to show eggs in its feces fifty-four days after the first lamb was infected. While the second lamb did not show as high an egg output as the first one, it eliminated 10,900 eggs per gram of feces at the peak of egg production. The estimated total output of stomach worm eggs by these two lambs at the peak of egg production was 8,770,000 eggs in a single day by the first lamb and 7,260,000 eggs in a day by the second lamb. This maximum was gradually attained and the output then gradually declined.

In the light of such evidence, it is clear that slight initial infestations with stomach worms deserve serious consider-

ation and warrant treatment, since apparently unimportant infestations may pile up tremendously in the course of a single summer and lay the basis for serious losses among large flocks.

While the pathogenicity of the stomach worm to sheep is generally recognized by farmers, it is important to remember that stomach worms are also of common occurrence in goats and calves and that these animals are by no means unaffected by infestations with these worms. Treatment and control measures for stomach worm infestation should not stop with sheep if goats or calves or both of these groups of ruminants are known to be infected.

Controlling Stomach Worms

The control of stomach worms involves a combination of treatment and rotation of pastures and of stock. In view of the great fecundity of stomach worms and the rapidity with which their life cycle is completed, no practical system of rotation, effective for the control of these parasites, has been devised, and it is exceedingly doubtful that it will be possible to control haemonchosis in ruminants by prophylactic measures alone. Treatment alone and combination of treatment and rotation of pastures and of stock are both effective in controlling stomach worm disease to a point which makes sheep raising possible and profitable; but, under American farm conditions, control measures which have not included treatment have usually been unsuccessful.

So far as concerns prophylaxis for stomach worm infestation by rotation of pastures and of stock, these measures are indicated and should be used wherever possible. In connection with rotation of pastures it is important to remember that areas not occupied by sheep for a few weeks or a few months should not be considered free from stomach worm larvae. While many larvae doubtless succumb to unfavorable conditions, such as drying, freezing and other environmental influences, other larvae, more favorably located on a pasture, may survive for long periods, despite unfavorable conditions. The maximum survival period for the eggs and larvae is unknown, but it is conditioned by such variable factors as temperature, moisture and other external influences.

The obvious advantages in pasture rotation are a diminished concentration of the eggs and larvae because of their wider distribution, and the certainty that more or less of the infective material on pastures will die off while the latter are not occupied by sheep. So far as rotation of stock is concerned, sheep should not follow cattle or goats, and *vice versa,* because stomach worms and other species of roundworms of ruminants are transmissible from one host species to another. Pastures previously occupied by horses or swine are relatively safe for ruminants, and *vice versa,* so far as parasites are concerned.

Other Gastrointestinal Parasites of Ruminants

Cattle, sheep and goats harbor numerous species of injurious roundworms other than stomach worms. Hookworms, nodular worms, ostertagids, trichostrongylids, nematodirids and other species of strongyles are usually abundant in the gastro-intestinal tract of ruminants. Some of these parasites are decidedly pathogenic when present in large numbers and are potentially and sometimes actually as harmful as stomach worms.

These roundworms have life histories essentially similar to that of stomach worms and, for this reason, some of the control measures taken with reference to the latter will help to keep down infestations with various other nematodes which occur in the gastro-intestinal tract of ruminants.

Lungworms: Lungworm infestation in

ruminants is caused by roundworms which have a direct life cycle, infestation resulting from swallowing infective larvae which develop from eggs eliminated from the feces of infested animals; sheep are also affected by heteroxenous lungworms transmitted by land snails. In the absence of effective treatments for lungworms, the indicated control measures are rotation of pastures and of stock and isolation of infested animals to keep the parasites from spreading to unaffected animals. Infested animals that cough and show other symptoms of lungworm disease require nursing treatment to tide them over the critical stages of infestation.

Liver flukes: Liver flukes are responsible for heavy losses among domestic ruminants, sheep and goats suffering more severely than cattle from this parasitic infestation of the bile ducts. In certain areas sheep practically disappeared as a result of grazing on infested pastures. In past years the sheep population of certain European countries was decimated by liver fluke infestation, and in the absence of proper precautions to control this parasite, many areas in the United States, principally along the Pacific Coast, in the Rocky Mountain States, in the South and Southwest will become unsuitable for raising sheep. Cattle are less seriously affected than sheep and goats. However, infested cattle do not thrive and are rather difficult to raise to market condition. Moreover, the livers of flukey cattle are condemned under meat inspection procedure, this condemnation constituting a serious loss to the live-stock and meat industries, considering the value of beef livers in the human diet and more particularly in the treatment of anemias.

Each fluke is capable of producing about 100,000 eggs, which are eliminated in the feces of the infested host. The miracidium which hatches from each viable egg lives only a few hours unless it finds a suitable lymnaeid snail into which it penetrates. The development in the snail is rather complicated and involves a number of larval stages, the final developmental stage in the molluskan host being a cercaria which leaves this host and encysts on aquatic vegetation or floats freely as a cyst on the surface of water. A single miracidium can give rise to 150 to 320 cercariae, a single fluke in the bile ducts of sheep can give rise, at least theoretically, to as many as 32,000,000 cercariae, each cercaria being capable of developing into a mature fluke in a suitable definitive host. This is, indeed, a reproductive capacity run riot.

Control measures for liver flukes involve the destruction of aquatic snails by draining or filling of wet pastures or by killing the snails with chemicals. Drainage is the best procedure to adopt in regions where it is practical to do so. Where it is impossible to drain or fill wet pastures, the dangerous areas may be fenced off to prevent ruminants from having access to them. Where none of the above procedures appear practical, it is still possible to control liver flukes by means of copper sulphate. The crystals of copper sulphate may be dissolved in running water which flows over the snail-infested pastures. The crystals or powder of copper sulphate may be broadcast by hand or powder dusters over large areas. A dilution of one part of copper sulphate to 500,000 parts of water will kill snails in twenty-four hours.

Since the prevention of liver fluke infestation involves a modification of the environment where ruminants graze, objections have been raised to the control measures outlined in this paper. Some persons interested in the preservation of wild life and in retaining certain areas under primitive conditions see in the liver fluke control program a threat to the nation-wide wild life conservation

program. In so far as this objection is limited to control measures on the public domain, it can be sustained as having merit. The objection to the broad program of liver fluke control on privately owned agricultural land is without merit, however, and naturally meets with opposition from the owners of live stock. Man has a right to transform his environment as a measure of protection to himself and the animals which furnish food, clothing and power on the farm. This history of civilization is an almost uninterrupted story of the modification of ecological conditions to develop agriculture, build cities, construct roads, exterminate harmful and noxious animals and plants and otherwise transform man's primitive environment in keeping with the demands of an advancing civilization. In the final analysis, snails that transmit liver flukes to domestic ruminants are no more useful to mankind than are tsetse flies, mosquitoes, ticks, lice, fleas and a host of other disease-transmitting invertebrates that threaten the very existence of mankind and the beasts on which he depends for food and clothing.

Summary

Summarizing the essential facts which should be kept in mind in connection with the control of parasites and parasitic diseases of live stock, the attack on the parasites present in the host must be supplemented by an attack on the infective stages which are present in the host's environment. The latter involves such procedures as supplying clean pastures, rotation of pastures and of stock, special care of young animals to protect them from gross parasitism while they are still highly susceptible to the injuries which parasites inflict, proper disposal of manure to cut down pasture infestation, control of intermediate hosts, a sanitary water supply and similar hygienic procedures.

The complete eradication of worm parasites of live stock is only a theoretical possibility, but is an ideal worth striving for. The practical goal in livestock sanitation, so far as worm parasites are concerned, is control to a point which will cut down losses resulting from infestations with ascarids, stomach worms, kidney worms, lungworms, strongyles of various sorts and other injurious internal parasites. Considering the great fertility of parasites and the marvelous adaptations which these pests have developed to enable them to cope with their environment inside and outside of the host, even under unfavorable conditions, the reduction of the number of parasites to a point where they do comparatively little harm is a goal worth attaining.

COLOR AND PIGMENTATION

WHY THEY SHOULD INTEREST US AS BIOLOGISTS

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As a preliminary to the discussion of this topic, it seems worth while to orient ourselves by considering what we mean by color and pigmentation. This because there has been considerable confusion in the use of these terms, with some resulting confusion of thought.

By the color of an object, we mean the quality of the light which it transmits, if the object is transparent, or which it reflects from its surface, if the object is opaque. The rays which are not transmitted or reflected are absorbed. If all wave-lengths are absorbed equally and completely, we call the substance black; if they are absorbed equally but incompletely, we call the substance gray; if they are reflected equally and completely, we call the substance white. If the various wave-lengths of the incident light are absorbed unequally, so that only certain rays are reflected or transmitted, we call the substance "colored" in the narrower sense of this term. I must agree with those who prefer to restrict the term color, so far as practicable, to this differential absorption and reflection of the various components of white light. There are those, to be sure, who include black, white and gray among the colors, and are compelled, accordingly, to distinguish "chromatic" and "achromatic" colors. This would seem to be doing violence to our language. However, it is important at times that we should have some inclusive word covering both the colors and the shades of animals, and thus the continued use of the term "animal coloration," in this broader sense, seems inevitable.

Color, as is well known, may result either from the chemical constitution of an object or from certain physical properties of its surface layers. In the latter case, we are dealing with what are termed "optical colors." For the former I know of no very satisfactory term, unless we call such colors "chemical colors."

The word "pigment" is one which has not always promoted clear thinking. As commonly employed, the word is applied to a great variety of colored substances, though by no means to all. Since it is a word of Latin origin, based upon a verb meaning "to paint," we may fairly infer that it was originally applied to substances used as coloring matters. A pigment was something employed by man to color something else. On this basis, we should regard ferric ferrocyanide and red lead oxide, for example, as pigments, while many other colored substances, such as copper sulfate and potassium bichromate, would not be so designated. Or perhaps the two former are to be regarded as pigments only when they are actually used as such.

In biology, a new criterion seems to have been adopted. From applying the term pigment to something which we ourselves employ to color something else, the meaning seems to have been extended to include anything which chances to give color to anything else. And so we have a whole series of "pigments" in the blood and bile and urine, in addition to those externally visible ones which color the skin and hair and feathers.

The situation here is rather curious. The urine, for example, is a solution con-

taining many ingredients. One or two of these happen to be colored. Though present only in minute quantities, and of secondary importance physiologically, these colored substances have been given a unique status as "urinary pigments." It is difficult to see why, in their own right, they are entitled to be classed as pigments, since we do not employ this term for colored substances in general. They are pigments only by virtue of their giving color to something else—in this case the urine.

Again, it chances that those constituents of the blood of animals which are most actively concerned in conveying oxygen are more or less highly colored substances. Accordingly, there has emerged a considerable series of "respiratory pigments." That the colors of these substances, as such, bear any relation to the respiratory function I do not think is contended by any one. Nor is it contended, so far as I can learn, that a substance playing this rôle need be colored at all. Then why "respiratory pigments"? With all due deference to those who know infinitely more about the physiology of respiration than I do, I would suggest that the oxygen carriers of the blood be designated by some more appropriate term.

We seem to be departing less from strict etymological usage when we turn to those "pigments" which give color to the skin or its derivatives on the external surface of the body. These would seem to be present in the rôle of coloring matters and nothing else. Their function in determining the appearance of an animal would seem to be as indisputable as that of the artificial pigments with which our Indian braves formerly painted their faces, and our civilized ladies do at the present time.

However, even here, the use of the word "pigment"—I now refer only to the natural ones—has tended to introduce an insidious error into our thinking. We have been prone to make the unconscious assumption that these "pigments" were there in order to give color. It is difficult to divest the word of its teleological significance.

In the days before Darwin, the colors of animals, or some of them at least, were regarded by many as having been created for man's esthetic satisfaction. Darwin, Wallace and others directed our attention to the possible utility of animal coloration to the animals themselves, either by way of affording them concealment or giving them a warning aspect or producing a color-scheme calculated to charm the opposite sex. In any case, it was the appearance of the animal, as perceived by another seeing organism, which was the essential feature of the adaptation.

I would be one of the last to question the frequent utility of color, as such, to animals. I am more disposed than many biologists to believe in the supreme importance, at times, of concealing coloration. Any merely physiological or biochemical account of the origin of these pigments, divested of the ecological setting of the animals concerned, would be utterly inadequate in many cases. It would furnish no clue whatever to the distribution of color—the color patterns—of numerous animals, and least of all to the origin of the elaborate mechanism controlling the color changes of many others.

But there is surely no inconsistency in my following this declaration with an equally emphatic one to the effect that much, perhaps most, of the coloring of animals is a mere by-product of their metabolism, having no relation to ecological needs. Colored substances may or may not have a rôle to play in the economy of the organism. When they do, this rôle may or may not have anything to do with the animal's external appearance. In any case, we must not confuse the question of the utility of a

given substance which chances to be colored, and the utility of the visible color which this imparts to the animal possessing it.

In view of these various considerations, I should be disposed to restrict the word pigment, in animals, to the substances responsible for their external coloration, including perhaps these same substances when they are encountered internally. Such substances are the only ones which ever truly function as coloring matters, that is to say as pigments, in the proper sense of the word, and even these probably have no such significance in a large proportion of cases. As to the "pigments" of our internal tissues and body fluids, and particularly the "respiratory pigments," let the verdict be "thumbs down."

That these suggestions of mine will have any effect upon current usage is too much to expect. Our mores, both as to the use of words and of pigments themselves, are little influenced by argument.

Let us, in conclusion, repeat the question: Why should biologists pay any particular attention to those objects or substances which chance to absorb and reflect light selectively? Why all this pother about pigment and coloration in animals? Our answers must be various. Some of them are rather obvious.

For one thing, colors and color patterns are frequently among the most conspicuous visible characteristics of animals. They are often the chief differential characters by which we distinguish one species from another.

Then, too, colored substances are much more readily perceived and recognized than colorless ones, and their spectral absorption bands figure prominently in their identification. These circumstances doubtless account in part for the attraction which the animal and plant "pigments" have for the biochemist.

Again, the colors of many animals bear very obvious relations to particular features of their environment. In some cases, colors are such as to render the animals extraordinarily well concealed in their more usual habitats; in other cases, we have the opposite condition of a high degree of conspicuousness, and again we have the well-known correlations between pigmentation and climatic factors. We still await adequate explanations of most of these phenomena.

Finally, we must recognize an element in our interest which is not scientific at all, though I half suspect that it is the most potent one for many of us. I refer to the esthetic appeal. A world without color would be a drab affair in more senses than one. Personally, I doubt whether I should be studying fishes, if they all looked like the pickled ones in our museum jars. Few of us have probably lost our childish preference for colored objects. It is my guess that even the concern of our physiologists over the bile and urinary "pigments" is an unconscious manifestation of this same infantile trait.

However that may be, color has figured importantly in nearly every branch of biology: in biochemistry, physiology, pathology, histology, taxonomy and genetics, both of animals and plants; as well as in psychology, both human and comparative. From whatever direction we approach the study of life, we can not escape the phenomena of color.

ISOSTASY

By Dr. WILLIAM BOWIE
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ISOSTASY, which has taken a rather prominent part in earth studies during the past few decades, has been much abused by both its friends and its enemies. Some of its most ardent admirers are inclined to think that it is a cure-all for every ill that afflicts Mother Earth. The acceptance of isostasy has been retarded much more by the inconsiderate stand of some of its friends than by the adverse criticisms of its opponents. There is a middle ground that we should take. There is no question but that isostasy in its general aspects, at least, is true, but there is much to be learned regarding details.

In future isostatic investigations and studies of the part that their results are to play in the general sciences of geophysics and geology, we must not depend upon the geodesist and the seismologist only, but also upon the geologist, the physicist, the chemist and the mathematician. The problems connected with isostasy and the application of the results of isostatic investigations to other branches of science are complicated. They require the combined thought and action of many groups of research workers.

The time has come for an attack on the problems of geophysics and geology with the earth treated as a unit. If we should solve some of the world-wide problems, then we could better understand the problems that are of a local character.

Isostasy is a most logical idea. According to it, the earth, approximately 8,000 miles in diameter, has an outer layer of moderate thickness, called the crust, that may be likened to a continuous strong blanket. A number of investigators, using different sets of data and several hypotheses, have derived thicknesses of the crust which lie between 40 and 125 kilometers. With more abundant geodetic data, more accurate values of the crustal thickness can be derived. It will probably be found eventually to lie somewhere between 40 and 80 miles.

The isostatic condition requires that the outer shell have residual rigidity and that sub-crustal matter have little or no residual rigidity to forces that act through geological time, say for hundreds, thousands or millions of years. It is not conceivable that with every shift of load on the earth's surface, no matter how small the load, there should be a corresponding sinking or elevation of the crust. The maximum load that the earth's crust can maintain without yielding is not known, but the gravity data that we now have indicate rather clearly that rock masses as great as a thousand feet in thickness extending over a wide extent of the earth's surface can not be supported for any great length of time.

It is reasonably certain that sediments deposited in shoal water can not alone greatly depress the crust. According to good geological evidence, sedimentary beds of 20, 30 or even more thousands of feet occur, and these sediments were deposited in shallow water. There must be an independent depression of the earth's surface to permit the accumulation of such thick beds. It is possible that these sedimentary areas were previously occupied by mountains or plateaus and that the change in temperature and

density of the crustal material resulting from erosion and maintenance of the isostatic balance may have caused the independent sinking.

The data, by means of which isostasy has been tested, consist of values of gravity and deflections of the vertical. For many parts of the earth the geodetic stations are widely separated. It is most desirable for the test of isostasy that intensive geodetic surveys be made over the whole surface of the earth, including the oceans. It is only by having large quantities of well-distributed data that we shall be able to solve the problem as to what degree isostasy is true for each limited portion of the crust.

The geodesists were forced to consider isostasy in carrying on their operations involving the derivation of a gravity formula, the determination of the figure of the earth and the computation and adjustment of arcs of triangulation. By using the idea of isostasy they have reconciled to a remarkable degree the observed and theoretical geodetic values.

One hears often, in isostatic literature, of gravity anomalies. An anomaly is merely the difference between the theoretical and observed values of gravity. An anomaly of one milligal, one millionth of gravity, is equivalent to the attraction of a layer of rock 30 feet in thickness and with the average density of surface rock. It is rather remarkable that isostatic anomalies as great as one hundred milligals are very rare. Such an anomaly would be the equivalent of an excess or a deficiency of three thousand feet of rock. We have many mountain and plateau areas that have far greater elevations than 3,000 feet and therefore we seem to be justified in concluding that even locally the earth's crust does not support extra loads, negative or positive, equivalent to 3,000 feet of rock with moderately extended horizontal dimensions. It has been found to be true, so far as tests can be made, that an isostatic anomaly as great as a hundred milligals is due largely to local causes. At stations that are not far distant from one having a very large anomaly, the anomalies in general are very much smaller.

Since isostasy is true in its general aspects, mountain systems and plateaus can not be extra loads, and therefore since those areas were at some time in the geological past below sea level receiving sediments from adjacent land areas, we must conclude that those areas have been pushed up. Whether the uplift was caused by horizontal or vertical forces is a major problem of the earth sciences.

Isostasy gives us a very good explanation as to why a mountain system exists for a great time in spite of enormous amounts of erosion. As material is moved from the surface, the isostatic balance is restored. If the difference in density of the surface and the subcrustal material is 10 per cent., the mountain will become lowered only 10 per cent. as much as the thickness of the material removed by erosion. Geologists have at times wondered how great beds of sediments could have come from previously existing mountains that must have occupied very limited horizontal spaces. It is seen from the above reasoning that the eroded mass may be five to ten times as great as that which was at any one time above sea level in the mountain mass.

There are two conceptions of isostasy, one by Pratt and the other by Airy. According to the former, changes in the elevation of the earth's surface are due to changes of density. According to the latter, the changes in elevation are due to a thickening or thinning of the crust caused by the action of horizontal forces. We do not now know which of these ideas is the correct one. Perhaps each of them

plays a part. It may be that the solution of this problem must be based upon a consideration of physics, chemistry and mechanics as they may affect the earth's materials. The geodetic data alone have been employed in the testing of the Airy and Pratt hypotheses, but it seems to me that we must bring other factors into the picture. However, it is possible, I believe, if we have much geodetic data in each of many mountain areas, to arrive at a fair conclusion as to whether the Airy or the Pratt hypothesis is the correct one. If Airy's idea is true, then under the highest mountains one would expect to find the greatest thickness of the crust. If Pratt's idea is correct, the depth of the crust should be nearly the same throughout.

Not only have we used the gravity anomalies to test the Pratt and Airy hypotheses, but we have assumed in many cases that the anomalies indicate exactly the extent to which the earth's crust may deviate from the isostatic condition. I think this view is erroneous. Instead, it is better to assume that a large isostatic anomaly at a gravity station may be due in large part to the presence of masses of abnormally light or heavy material close to the earth's surface and close horizontally to the station. This is notably true, for example, in the case of the isostatic gravity anomaly, nearly one hundred milligals, at Seattle, in the trough extending along the eastern margin of Puget Sound, in the state of Washington. At a station only 20 miles to the northwestward of Seattle, the gravity anomaly is very close to zero. Except for one station to the northward the other stations near Seattle do not have anomalies that approach 100. This indicates that the Seattle anomaly is caused by a local abnormal distribution of densities. If it were otherwise or if that anomaly were due to lack of isostatic balance under Seattle, the surrounding stations would likewise have very large anomalies.

In recent years the seismologists have been making notable progress in earth studies along their lines of research. They have found that records of waves from nearby earthquakes (less than 200 miles away) can be explained only on the assumption that some of the waves instead of following direct paths are reflected or refracted at surfaces of discontinuity whose depths can be determined. These surfaces separate the crust into layers of moderate thicknesses. The existence of the surfaces of discontinuity must be due to differences in the physical characteristics of the layers involved. But this does not mean, in my judgment, that the depths found for the outer layers of the earth's crust by seismological investigations limit the thickness of the so-called isostatic layer. I can imagine rocks of different kinds existing in distinct layers with each one of the layers undergoing changes in density, due to changes in heat and pressure, that would tend to balance the load of topography.

Many geologists are inclined to favor a very thin crust, but since there have been great changes in portions of the earth's surface during geological time, it would seem to be rather difficult to explain how these changes could have taken place with a thin crust. If changes of density cause changes of elevation of the surface, then the changes in density in many instances would have to be very great for the thin crust. If, on the other hand, the changes in elevations have been caused by world-wide horizontal thrusts, then we have the difficulty of explaining how a very thin crust can carry great forces through long distances and push up mountains and plateaus. I am inclined to think that the solution of many problems of geology and geophysics will be made easier if the

crust is assumed to have moderate thickness, say of the order of 60 miles.

If isostasy is true, then it would seem that the adjustments that maintain equilibrium must involve the horizontal movement of material below the crust. Erosion causes certain portions of the earth to be lightened and others to be weighted. The tendency will then be for subcrustal material to move from the sedimentary areas toward the erosion ones, but the stress differences will be in the opposite direction, or from the higher to the lower areas, until the depth of compensation, the lower limit of the crust, is approached. If this condition is true, then the isostatic subcrustal adjustment probably can not cause distortions such as folding and over-thrusting in the outer strata of the crust that lie over the large areas between the erosion and sedimentary zones.

Volcanology is a very important subject to be considered in isostatic investigations. There are outpourings of lava through fissures and the building up of great single mountains by volcanic action. Are these outpourings extra loads added to a block of the earth's crust? The answer to this question will depend upon the zones from which the volcanic material emanates. I believe the best opinion to-day is that volcanic matter does not come from subcrustal space but from within the crust itself. If this is true, the outpourings are extra loads on the earth's surface, but not extra mass added to the block of the crust beneath. The pressure exerted at the depth of compensation under an area in which there has been volcanic activity should be the same after as before it occurred.

As a result of erosion and sedimentation, changes of temperature of substantial amounts must take place in crustal material. The crust under areas of sedimentation is pressed down into hotter zones and under areas of erosion it moves upward by isostatic adjustment to colder zones. Eventually the isogeotherms resume their normal positions or depths and in consequence the crust is made hotter or cooler. The changes in temperature should cause changes of physical or chemical states of the crustal matter and result in changes in density. It is possible that the uplift of areas to form plateaus and mountains and the depression of other areas to form troughs may be due to changes in density resulting from changes in temperature.

It is important that an isostatic adjustment be made of all geodetic data in the form of deflections of the vertical and values of gravity. Methods have been developed that can be readily used. After the reductions have been made on one system, factors can be used for computing the effect of the compensation on other systems. Necessarily in making the isostatic reductions one should have a knowledge of the topography. It is only where there are topographic maps that indicate by contours the masses above sea level and charts that show deficiency of mass in ocean waters, that the isostatic reduction can be made with exactness. When the stations are on extended plateaus accurate topographic maps are not so necessary, since for such areas the effect of compensation is nearly the same as that of the topography, regardless of the assumed thickness of crustal material.

In our efforts to explain what has caused horizontal and vertical movements of crustal matter we must not do violence to fundamental principles of mechanics. It is not logical to assume that great and world-wide horizontal forces have been active without having a logical explanation of the origin of those forces. It is reasonably certain that thin strata can not be pushed uphill against gravity and against shearing and frictional resistance, or at least that such

a movement can not be great. Overthrusts of thin beds of strata do not mean that the whole crust of the earth has been involved. Even the overthrusts of strata of a mile or more in thickness, for great distances, present very difficult problems to explain. What is the cause of a comparatively small amount of strata moving great distances? Is it not possible that much that is called overthrusting is really underthrusting with the strata involved moving down slopes under the influence of gravity? It is my belief that we shall eventually reach the conclusion that the predominant forces are vertically-acting ones and that horizontal movements of strata are incident to the vertical movements.

According to the best geological evidence available there are few or no indications of horizontal movement in extended plateau areas. Therefore, it would seem to be logical to conclude that the cause of the elevation of the plateau surface is a change of density rather than the action of horizontal forces. Is the uplift of a mountain system entirely different from that of a plateau?

The isostatic studies are of great interest in the realm of pure science, but they have a practical value. Isostatic reductions are now being made by some petroleum companies searching for oil. It is probable that gravity and deflection of the vertical data, when isostatically reduced, help to discover oil, ores and, what is of great importance, undergroundwaters. The governments of the world and many private companies can well afford to help finance the prosecution of these lines of investigation. I believe that by such work great economies can be made in efforts to discover and utilize certain natural resources. It is hoped that private agencies conducting geodetic and geophysical surveys and isostatic investigations will make their data available to the scientific public after the information has served the special purposes for which it was secured.

THE DIESEL ENGINE AND ITS POSSIBILITIES

By SUMNER B. ELY

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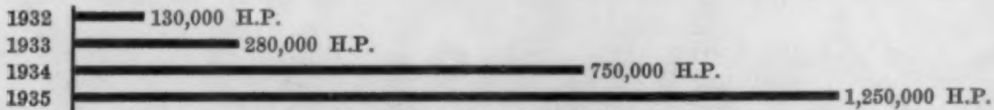
At the present time the public is Diesel-minded. A year or more ago stream-lining absorbed the public interest; and before that, at various times, radio, free-wheeling and other engineering ideas and novelties. Public opinion is not always logical or sensible over such matters. For example, at one time enthusiasm was so great that everything possible must be stream-lined. It became a veritable craze, and absurd advertisements appeared, such as "stream-lined roller skates," "stream-lined shoe brushes," etc. As a matter of fact, an automobile must travel at least fifty-five miles an hour before any appreciable saving will result from stream-lining.

To-day much the same thing is happening with the Diesel engine. We hear that we are now entering the "Diesel age," and we read in the papers that we are to ride to prosperity on the stalwart cylinders of the Diesel engine. However much this may be exaggerated, there is some very good background for public interest, as will be seen by a glance at the diagram of horse power of Diesel engines produced. The growth of the Diesel industry is indeed spectacular, and particularly in view of the fact that it occurred during depression years. This growth, among other things, such as the wide publicity given the successful innovation of the stream-lined Diesel-electric trains, has fired the public imagination, and it is no wonder that the Diesel industry has been heralded to miraculously pull us out of the depression.



Production of Diesel Engines in the United States
An increase of nearly 1000% in three years.

Young men trying to earn a living have naturally turned to this supposedly new field, and as a consequence we find a large number of Diesel schools which have sprung up over the country. These schools are generally of a "practical" nature, where a small amount of theory is given with opportunities to observe an engine in operation or even to dismantle and assemble Diesel engines. The criticism advanced against them is that they not only promise to turn out an expert in a very short time, but assure any one who will take their course a certainty of immediate employment. As a matter of fact, there is little demand for Diesel mechanics and service men in the Pittsburgh district at the present time.

However, while at present the demand may be small, it is well to remember that in the last two or three years, several thousand busses in London have been changed from gasoline to Diesels, and many men have been needed. In our own country Diesel busses are being used more and more on our through routes.

Some of our colleges and technical schools have tried to help out by popular evening courses, but adequate equipment in almost every case has been lacking; so too with high-grade technical education. While the fundamental principles are already included or can be included in existing courses, good examples of Diesel engines are needed in laboratories or

elsewhere. There are in the United States few colleges with suitable equipment to offer graduate courses in Diesel engineering. This information is the result of a recent questionnaire.

As almost every one knows, the gasoline engine used to-day in our automobiles consists of a cylinder, having in it a piston which is driven by an explosion of gasoline vapor. The reciprocating motion of the piston, through a crank, connecting rod and gears, is turned into circular motion at the wheel of the automobile.

To obtain an explosion (and explosion is nothing but very rapid burning), there must be a mixture of air and gasoline vapor, and in the proper proportion. The carburetor accomplishes this mixing by automizing liquid gasoline and metering the amount of air supplied. However, the carburetor can not properly atomize a heavy liquid. It must be supplied with an easily vaporized liquid fuel, such as gasoline, which has been derived from crude petroleum.

The first indictment against the present-day automobile, therefore, is that it can not utilize heavy oil fuels, which are comparatively cheap now.

In the early days of the internal combustion engine, it was discovered that an explosive mixture must be put under pressure before it is ignited; otherwise, instead of a quick, sharp explosion producing a high pressure, a long, slow burning with very little pressure results. Compression of the charge before explosion is absolutely necessary for the proper working of the engine. This is obtained in most of our automobiles by letting the piston fill the cylinder on its outward stroke, drawing in the mixture from the carburetor; the valve then closes so the mixture can not escape, and on the return stroke of the piston, it is compressed into a small space left in the end of the cylinder. The smaller this space, the higher will be the compression, which is commonly around 100 pounds to the square inch. The compressed mixture is now ignited by a spark plug, and the resulting explosion drives the piston on its outward stroke again, but this time developing power.

It is a well-known fact that the higher the compression before ignition, the greater is the efficiency of the motor; and the aim of the engineer is to increase the compression as much as possible. But here he soon reaches a limit. Any compressible substance, such as air or gasoline vapor, when compressed becomes warm; and the harder it is compressed, the hotter it gets. We all know how small hand air pumps get warm, and in large air compressors it is necessary to surround the cylinder with cooling water to prevent overheating and burning of the lubricating oil.

And so with the gasoline-vapor-air mixture; if compressed too much, it will become so hot as to explode spontaneously, without any spark whatsoever. This, of course, must not happen, as the time of the explosion must be controlled to prevent backfire and detonation. Each fuel has its own auto-ignition point. No-knock gasoline will stand higher compression than ordinary gasoline.

We may then make a second indictment against the present gasoline motor, *viz.*, the compression pressure and consequently the efficiency are limited.

About 1890 an engineer named Rudolph Diesel took out some German patents which were ultimately tried and worked out with the assistance of the German firms of Krupp and M.A.N. Diesel's idea was very simple, *viz.*, to do away with a carburetor and during the forward piston stroke to draw into the cylinder pure air only. On the return stroke this air was very highly compressed to some 500 or 600 pounds per square inch, which would bring it to a red-hot heat. Unlike the gasoline motor, no auto-ignition could take place, as pure air alone can not explode or burn. Into

this small volume of red-hot air, caught at the end of the stroke, liquid fuel was forced by means of an injection pump. The fuel of course would immediately burn and drive the piston forward again on its working stroke.

Here, then, is an engine which is simplified by having neither carburetor nor spark plug, although a somewhat complicated injection system has been added. Furthermore, it possesses two great advantages: (1) The ability to use cheap, heavy fuel oil; (2) due to the high compression, it has the highest known thermal efficiency.

The Diesel engine, as built to-day for equal powers, will use only about one half the quantity of fuel required by a gasoline motor; and in addition will use a much cheaper grade of fuel. The objection is often raised that if in the future the demand for Diesel fuel oil greatly increases, probably the lawgivers of this country will see fit to tax it as heavily as gasoline is taxed to-day. But even then there would still be a saving of one half the amount used. It has been estimated that in the Pittsburgh district the Diesel engine to-day could afford to pay for its fuel oil four times its present price and still produce power as cheaply as a gasoline engine. Furthermore, while the tax on fuel oil in the future may be increased, there will be great pressure brought to bear on the part of the oil companies to keep it down. The great bulk of fuel oil produced is used for other purposes than generating power in oil engines, and if its price becomes too high, these users will go to coal or other fuel, and the oil companies will find themselves left with a very restricted market.

To offset this great saving in fuel, however, the Diesel has a higher first cost and is heavier than the gasoline engine. It was stated above that the Diesel cylinder compression pressure was as high as 500 or 600 pounds per square inch; and after the oil is injected its combustion may raise it to 800 or 900 pounds or more. In the gasoline engine, on the other hand, the maximum pressure after explosion will seldom exceed 400 or 500 pounds per square inch. The Diesel must have thicker cylinders and stronger parts to resist the greater pressure and is consequently heavier and more costly. To express this in another way: due to the high compression and long expansion, to get the same *average* pressure per square inch on the piston throughout its working stroke, the *maximum* pressure is greater in the Diesel.

In the last analysis the Diesel will succeed or fail on its commercial efficiency. The cost of generating power is not a matter of thermal efficiency alone. We must take into account the interest on the investment, the cost of repairs, maintenance, wear and tear, length of service, etc., and this can only be determined by operation over a period of years. The Diesel engine has now been in operation for some twenty-five years and has demonstrated its worth. It does not seem to be generally known, but the fact is that to-day more than 50 per cent. of our shipping is equipped with Diesel engines. We perhaps think that this is so because the internal combustion engine does away with the inconvenience of a boiler; but records show that medium-speed ships that are constantly in service are equipped with Diesel engines, while those remaining in port for long periods have cheaper steam installations. In other words, where a great deal of fuel is to be used, it pays to make the larger investment and use the better saving equipment—a matter of dollars and cents.

In Europe, where fuel is expensive, we find many more Diesel engines than in America, where fuel is cheaper. The registration in Germany alone for 1935 was over 30,000 Diesel trucks, busses and automobiles, and it is estimated that the Diesel engine manufacturers of Europe together turn out 4,000 trucks and busses

monthly. To this must be added the Diesels installed in stationary service.

And in the United States we have already some fifty well-established Diesel engine manufacturers. They have stationary Diesels of moderate capacity in all kinds of service; lighting plants, pumping plants, ice plants, cotton mills, flour mills and in all sorts of industrial work. There is a growing demand for them in large office and hotel buildings. In many cases where steam power is already installed and the exhaust used for heating the building in winter, Diesels have been added, not only to increase the power of the plant, but to save the expense of operating the steam plant in summer. For example, the Hotel New Yorker has lately added 750 Diesel H.P., and 525 H.P. is installed in the Singer Tower, New York City.

The great impetus given the Diesel in the last few years has come about largely by improving the method of injection. The older Diesels injected the fuel oil by means of an air spray, in order to help combustion and regulation. This meant outside additional pumps and auxiliary apparatus. The Diesels built to-day are self-contained and the fuel oil is injected "solid" without air spray. This improvement has been accomplished by proper injection atomizing nozzles and pumps and by properly shaped combustion chambers, and has greatly simplified the engine.

Diesel installations are scattered widely throughout the United States; the demand for them of course varies in different localities, depending to a great extent on the cost of fuel in that locality. As a consequence, in the Pittsburgh district, where coal fuel is comparatively cheap, we find few installations; although there are a number of Diesel tractors and power shovels working around Pittsburgh and several river boats have Diesel engines. A number of large Diesel manufacturers have already established offices in Pittsburgh, and must believe there is a good Diesel field here, in spite of low coal fuel prices.

Regarding the application of the Diesel to automobiles and airplanes, the chief requisite is light weight. The power developed by an engine is a function of its speed. Consider an engine developing a certain horse power at a certain number of revolutions per minute. Using the same amount of fuel per revolution, if we can double the revolutions, the engine would use twice the total fuel and develop approximately twice the horse power; not exactly twice, as friction would modify it. However, the higher the speed of an engine, the more horse power is developed for the same weight, within limits.

The gasoline engine has the advantage of speed over the Diesel. A Diesel cylinder of the same power must be thicker to resist the higher pressures, and its piston and moving parts must be heavier. These reciprocating parts must stop and start at the end of each stroke. A gasoline automobile engine will run 3,500 or more revolutions per minute, which means starting and stopping them 7,000 or more times in a minute. The weight of reciprocating parts at high speeds is very important, for the engine may not stand up in service under the severe stresses they produce. Diesels do not generally exceed 1,000 or 1,500 revolutions per minute. A few have been built and operated at higher speeds, but they are more or less experimental and not tried out by much length of service.

As stated above, for equal powers, or equal size cylinders (same M.E.P. and same R.P.M.) the Diesel is heavier than the gasoline engine. But further, if the gasoline piston runs faster, its cylinder can be smaller and still produce the same power. Therefore, the gasoline engine has the additional advantage of smaller size per horse power due to its greater speed, which reduces the weight comparison still further.

All this means that the Diesel engine, if applied to an automobile, must run more slowly and therefore be larger and cost more than the gasoline motor. Of course the saving in fuel under some conditions may more than offset the additional expense; and in Europe we find quite a number of automobiles with Diesel engines. There are no Diesel-engined automobiles in the United States, except possibly an experimental one here or there. Should we start to apply Diesels it would mean larger, heavier and more expensive cars; and under present fuel conditions here, it seems hard to believe that the public would pay the increase.

While we may not see Diesels applied to passenger cars in this country, it looks as if the Diesel was likely to take over the whole field of trucks, busses, tractors and transportation machinery where slower engines are used, and fuel cost is an important consideration. We find great numbers of these machines now in the United States, particularly in the West, working on farms, earth stripping, road making, in logging camps, etc. The Caterpillar Tractor Company on January 1, 1935, made the statement that they had 28,352 tractors in service.

Regarding the airplane, its propeller, to be efficient, should run around 1,800 or 1,900 revolutions per minute. Diesels have been made to run at such speeds, and some airplanes have been equipped with them; but as already stated, for equal power developed, the gasoline engine is lighter; and as weight is such an important consideration, the Diesel is not likely to become popular with airplane builders. Furthermore, in order to reduce still more the weight of the airplane, we have lately seen high-speed gasoline engines used. Instead of directly connecting the engine to the propeller shaft, gearing has been used, allowing the engine to run at a greater speed and thus to decrease its weight for the same power.

When we come to consider very large installations, such as great central electric generating stations and our very large ocean ships, here again the Diesel is at a very distinct disadvantage. There is a limit to the size of a Diesel cylinder. If the diameter exceeds 35 or 40 inches, it is very difficult, with the high temperatures which constantly occur, to prevent the cylinder heads and bodies from cracking. And even if a successful cylinder of very large diameter could be built, it would be too heavy and cumbersome for practical service. The consequence is that large powers can be obtained only by using a great many cylinders. This involves great expense, immense weight and a very large space in which to house them. This is also true of steam engines.

Compare this with the present-day steam turbine, which can be built for enormous horse powers so compactly as to be easily operated and manipulated, and of less first cost and much less weight. In the turbine immense volumes of steam blow through a long cylinder in which is a rotating piece only, with no reciprocating parts to limit the volume of steam taken in. Steam turbine units can be built to generate 50,000, 60,000 and more horse power; whereas a ship such as the *Saturnia*, having 20,000 horse power of Diesel engines, is a very large installation indeed. There are sixteen cylinders, 36″ diameter × 42″ stroke, and the reciprocating parts of each cylinder weigh something like four tons. Special tools and devices are necessary to get at the inside of the cylinders to examine and repair them. Of late years, too, the thermal efficiency of the steam turbine has been improved; and while not as high as that of the Diesel engine, we may be very sure that steam will still be used to produce our great powers.

THE UNITED STATES COAST AND GEODETIC SURVEY AND THE PROPERTY OWNER

By PHILIP KISSAM

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THE ownership of land is perhaps the most fundamental economic consideration. Through the ages, primitive tribes have fought for the possession of land or for the right to hunt and fish in certain areas. To-day nations contend with each other for control of the land. Under whatever political scheme a state is organized the dedication of certain parts of the land for ownership or for definite uses is preeminent in importance. The life blood of a democracy depends upon the right of the individual to own, under certain restrictions, a definite division or portion of the commonwealth. The very development of civilization is dependent upon the allocation of real property for designated uses either by individuals or the state. For this reason the position of land division lines or land boundaries is of singular importance.

It is unbelievable, but nevertheless the fact exists, that in the United States it is next to impossible to accurately determine the precise position of any land boundary. State lines are sometimes in doubt; the boundaries of public rights-of-way (highways and streets) are notoriously intangible; and the positions of private holdings which depend upon the actual location of streets and roads are seldom, if ever, positively determined. The average property owner, complacent in the false security that his fence lines mark the boundaries of his property or that his place of business is built on the city lot he has purchased, seldom gives serious thought to these conditions. A survey has been made, his property is carefully described in a recorded deed. Why should he go further to assure himself that no one can eject him from his holdings? But let us inquire a little further into the actual facts. How was this survey performed? Or, how was this careful description procured? How dependent are these locations of his fences or buildings on the judgment of the surveyor and how dependent on his skill?

Let us look for a moment at the sequence of events by which this particular parcel of land was determined upon. Original title must be acquired by force of arms. Through this means the land becomes the property of the king or state. By grant or sale the land is then divided among original proprietors. Mountain ranges, natural waterways, etc., mark the boundaries of these grants. Such land marks are excellent for great areas but are useless when later they must be used to delineate city lots. As further division of the land occurs, natural features soon become inadequate. Artificial markers, known to surveyors as monuments, are erected to preserve the location of boundary lines; trees are blazed, stones heaped up; stakes or irons are set to mark positions. From their very nature such marks are temporary. With the loss of these markers disputes have arisen which can never find satisfactory solution. The force of circumstances has thus developed the common law practice which gives title of land to any one who believes that he owns the land, has defended the land from encroachment and used the land unchallenged for a certain term of years. Fences of themselves

become actual markers of boundaries, even though they may be originally built in a wrong position. It would seem that such a provision would effectively stabilize actual holdings. On the contrary, it usually introduces many complexities for the surveyor to solve. A fence may for convenience be built at one side of the line by agreement between both owners. There is always the possibility that a land mark may have been secretly moved by an interested party. The accepted boundary may have been contended less than twenty years ago. A fence or party wall can never be accepted as a boundary without careful scrutiny.

Written descriptions of the property based on surveys are recorded in the effort to stabilize the positions of the boundaries. A purchaser together with the vendor may temporarily mark the boundaries of the purchase. A survey of these marks is made with a steel tape and a transit, and thus the length of the various sides and the angles of the corners determined. The next step is the one which introduces all the difficulties. The surveyor must write a description of this property based on his survey. He can perfectly describe a piece of land of the correct shape, but how can he describe where the land is? He uses points of reference, either tangible or intangible. Whatever land mark he may choose, the utility of it is slight, because without question it will be lost or destroyed. Frequently he places monuments or stones, or iron pipes at the various positions. If these marks are in a town or city, sidewalks are built over them, they are removed for street or private construction; if in the country, they are covered by vegetation—all in a surprisingly short time. Usually he references his work to public rights-of-way. The boundaries of the public rights-of-way are the most indefinite of all. Since they are exempt from the common law, mentioned before, no individual can acquire parts of public property by fencing them in or building on them and holding them unchallenged for a term of years. Thus the boundaries of public rights-of-way are seldom carefully watched, and their positions are lost more quickly than private holdings.

Let us consider the next step in the division of land. The location of some property may be such that it is more valuable for residence or business purposes than for farming or other utilization of this soil. The ownership of small lots by many persons is the natural step toward further development. In order to advantageously sell one lot it is clear to the owner that a complete plan should be made so that future streets can be placed in their proper positions by reserving areas for them. He employs an engineer to work out a proposed plan and to compute mathematically the sizes and shapes of the various lots from the dimensions given in the original deed. A purchase is made and marks must be placed in the ground showing the location of that particular lot. The surveyor employed searches in vain for the original boundaries of the tract. With what skill and judgment he can muster he determines the location of the public right-of-way and the exterior boundary lines, and measuring from these he stakes out the lot or perhaps several lots. His judgment is called upon because what marks he finds are not consistent. With the measurements between them as recorded in the deed he must decide whether the marks he finds are in fact markers of the property, and if so, whether they are in their original position, and with what accuracy the original survey was made. As the cost of a survey is the direct function of the accuracy and the original tract was worth comparatively little when the survey was made, chances are very good that inac-

curacies are prevalent. Other lots may have to be laid out later by another surveyor. He too has no points of reference and the work of the previous surveyor may be lost. He too must use his judgment, and the relative position of the lots which he lays out to the previous lots and to the public rights-of-way is necessarily at variance with the plan. A new street may be established, which again must be located by judgment introducing a third variable.

The writer does not wish to infer that conditions of this kind occur in well-operated real estate subdivisions, but the greater percentage of the land is divided piecemeal and at various times as the need for it makes it an advantage to the owner to sell small portions. Perhaps 95 per cent. of the real estate in the country has changed from the farm to city lot in this way, landmarks being continuously lost throughout the process. The result, of course, is confusion, arguments, lawsuits and damage to title.

Let us follow the history of this land a little further. After it has become a residential or a business section of a town and a piece of property is to change hands, a surveyor is asked again to show the location of a certain parcel. In spite of the very careful description of the parcel found in the deed, it is fatal for the new owner to build on property marked out in accordance with this description. The surveyor must make a careful study of all the lot locations in the area. He must find just what is called for in the deeds of the properties within the entire block in which the lot is located, and perhaps even further away. He must find by careful instrumental determination where the lots actually are located on the ground, which of course again is difficult, as many of the marks will have been obliterated. After some period of careful research he can mark the property again according to his judgment. When he measures his final location, he finds that it does not agree with the original deed. Had he made it agree, the property would overlap the adjoining property, as there may be perhaps not enough land existing to satisfy the deeds in the area; or he may have been forced to twist the lot or move it this way or that from its deed location in order to eliminate discrepancies. Theoretically he should inform the new buyer of the existing situation. He should report the divergence in shape, size and position of the lot as he has marked it, from the location according to the deed. When so informed, the buyer should request the seller to procure a court ruling defining the position of the proposed purchase. As the chief evidence in such a court procedure will be obtained from testimony of the surveyor, the decision of the court would probably follow the lines of the surveyor's decision. Also little value would accrue to the buyer from this action as findings of the court could be no more permanently marked than the findings of the surveyor, even though the court decree would temporarily clear the title for the purchaser.

The usual procedure is much more simple. The buyer is entirely uninterested in the findings of the surveyor, after the surveyor has staked out the lot. He accepts a deed from the vendor containing a description of property which the surveyor knows is not consistent with the actual property. Moreover, should the surveyor suggest that a new and correct description, based on his survey, be included in the deed in place of the old description, the vendor might seriously object. The vendor must guarantee the title, and he is advised that it is easier for him to defend the title of the property if it is sold by the same description as the one by which he acquired the property, even though he may be guarantee-

ing title to something which is non-existent. The new survey is therefore thrown into discard and the old erroneous description kept. It is hardly necessary to point out that not only are surveys needlessly complex and costly but that titles are damaged and lawsuits encouraged. What is the keynote of the difficulty? What is the origin of this continuous confusion? *It is the lack of permanent well-known indestructible points of reference.* From the above discussion it is evident that such permanent points are extremely difficult to attain. What answer can be given?

Let us suppose that monuments were carefully set throughout the city or area involved in positions where they are least liable to disturbance. Let us suppose, then, that the *relative* positions of these monuments are determined with precise surveys. It is obvious that should any of the monuments be lost they could be replaced by measurements from the others. The permanency of each would be increased by the existence of the others. It is easily understood that the complicated angles and distances ordinarily required to describe the relative positions of many such monuments might burden the records and cause confusion. For this reason the method would be enhanced by the establishment of a system of plane coordinates. A system of plane coordinates is nothing more than a mathematical method of laying a rectangular grid over the entire locality. The position of each monument could be determined by expressing its distance accurately from a given north and south line together with its distance from a given east and west line. If the lines of reference are chosen far enough west and south of the given area, it will only be necessary to state the number of feet the point lies east and north of these lines of reference, *i.e.*, to give the "x" and "y" coordinates of the point, in order to completely describe its position. No mathematical difficulty is encountered in this procedure, if the angles and distances have been measured. In fact the rectangular plane coordinate system is so mathematically simple and advantageous that the positions of the property corners themselves should be described in this manner, making only a very simple computation necessary to locate the property from *any* monuments in the neighborhood.

How much better it would be if such a coordinate system were extended over an entire state, with monuments distributed throughout and connected by accurate surveys. Every property could be located accurately from any monument, its position could never be lost, discussions could not arise, and every monument within the boundaries of the state could be reset, if necessary, by measurement from any other monument.

The foundation for such a plan was laid in 1807 with the establishment of the U. S. Coast and Geodetic Survey. At that time a small system of triangulation was established in the metropolitan area of New York City, extending over parts of Long Island and New Jersey. Since that time, the net of triangulation has been extended to reach the Pacific Coast and cover the United States from Canada to Mexico. Thus there now extends throughout the country a vast system of marked triangulation points, their relative positions determined by precise surveys. The precision and accuracy found in the work of the U. S. Coast and Geodetic Survey has become a byword among engineers. Let me illustrate how accurate and permanent the positions of these points really are. A triangulation point marked by an earthenware cone buried two feet below the ground surface was established in New Jersey in 1839 in the course of the work of some of the earlier triangulation. Vegetation soon covered the scar in the earth which marked its position, and had it been a

boundary marker it would never have been seen again. But it was a triangulation station and it became desirable to find it. There existed a triangulation marker thirty miles to the south, and another forty miles to the northeast both of which had been set during the survey of 1839. By various systems of triangulation connecting with the old work, the relative position of the lost point with respect to these two old markers was determined. A monument was set on the same hill as the lost station. (The old records carefully described the hill.) An arc of triangulation was run seventy miles across country, connecting this new monument with the known triangulation points. With the results of this survey it was possible to compute the relative positions of the old point and the new monument. An angle was turned, a short distance measured, and a hole dug, and there, firmly set in the earth in the position calculated, appeared the old earthenware cone, lost from the sight of man for over ninety-seven years.

The U. S. Coast and Geodetic Survey has established plane rectangular coordinate systems for every state. In large states like Texas and California, several zones of coordinates are necessary. It might be asked, how can a plane coordinate system be applied to the curved surface of the earth? By using accurate projections plane systems can be extended over considerable areas without introducing material inaccuracies. These inaccuracies or "scale corrections" are of such a minor nature that the usual accurate survey will not show the discrepancy. Where the coordinates of a property corner have been determined, every monument in the entire national system acts as a witness point for that property corner, and its position is determined forever.

There are now in progress through the initiative and encouragement of the U. S. Coast and Geodetic Survey, in fourteen states, emergency projects for the purpose of establishing many thousands of monuments conveniently located along highways and streets and connected by surveys with the triangulation points of the U. S. Coast and Geodetic Survey. The relative position of each of these monuments is determined and their plane coordinates computed. They are set in pairs over one thousand feet apart, so that direction, as well as position, can be obtained from them.

Such is the service of the U. S. Coast and Geodetic Survey to the property owner. Although only recently available, this service has already passed the experimental stage. Government lands deeded by the Tennessee Valley Authority are described by this method. New Jersey has passed a law making the system the legal base for describing property within this state. Already many blueprints and plans of engineering development show monuments with their New Jersey plane coordinates. Large corporations are seizing this opportunity of permanently marking their lands. In the state of Massachusetts the Land Court now uses no other system. Public land monuments in Iowa are being surveyed for their state coordinates, so that they never again can be lost. France, Germany and England have been using similar systems for many years.

It is a great achievement that, in spite of every discouragement, lack of public appreciation, meager appropriations and underpaid personnel, the U. S. Coast and Geodetic Survey has spread this great triangulation net over the entire country and developed for the country this scientific method of permanently marking land.

THE AGES OF THE STARS

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According to the theory of relativity the total energy content of any material body, such as the sun or any of the other stars more remote from the earth, is directly proportional to the mass. Expressed in a mathematical form, this relation is

$$E = mc^2$$

where E is the energy, m is the mass and c is the velocity of light. For convenience, it may be further assumed that E is in ergs, m in grams and c is in centimeters per second. In this case c has the value of $3 \cdot 10^{10}$ or 30,000,000,000.

The theory of relativity makes no attempt in any way to predict the transformation of mass into energy; but through the above equation it specifies, rather, how much a body has decreased in mass and in weight when its energy content has in any way been diminished. In other words, the theory has nothing to say as to whether or not all the predicted energy is available.

Energy may appear in many different forms; and in most of these, if not all, the sun and the stars abound in it. At the distance of the earth from the sun (93,000,000 miles), however, most of the solar energy is manifested in the form of heat. In fact, all the energy utilized in any way by man may be traced to this source. An acorn grows into a tree by making use of heat energy absorbed from the sun's rays. When wood is burned, this energy is liberated, and part of it may be transformed into mechanical energy, as in the case of the steam engine. Inasmuch as the potential energy contained in thunder-heads and rain-clouds originates from the sun's heat, expended in converting water into mist and vapor and in raising it to great heights above sea-level, the electrical energy derived from water-power likewise owes its origin to solar energy. Energy from the wind may also be traced to the same source. In fact, the civilization of man has advanced according to his ability to apprehend and to exploit energy gained from the sun, until now he not only reassembles that intercepted by the earth in his own era, but from the coal mines and oil wells he is tapping the supplies stored up by the sun in the earth's interior millions of years before he appeared upon the scene.

Since c^2 is so enormously large ($9 \cdot 10^{20}$ or 900,000,000,000,000,000,000), a very minute quantity of matter corresponds to exorbitant supplies of energy, provided of course these supplies can be tapped. The converse is the well-known fact that the gain in weight by heating a body, although a reality, is much too small to be detected by ordinary methods. The magnitude of these statements can best be appreciated from a few simple calculations. It can be shown that in one ounce of matter, in any form, there is ample energy to lift 943,000,000,000 tons a distance of one foot. If this energy could be extracted, it would suffice to run an engine of 108,700 horsepower for one year. It would raise the temperature of 108,000,000 tons of iron 100 degrees, Fahrenheit, or would be sufficient to give this huge mass of iron a speed of more than 500 miles per hour. The converse of each of these statements is also true. That is, 108,000,000 tons of iron, for example, would decrease in weight one ounce by cooling from 100° to 0°, Fahrenheit; and 108,000,000 tons of iron, for example, would gain one ounce in weight as measured by an ob-

server at rest if its speed could be raised to 500 miles per hour.

Since the earth began, about 2,000,000,000 years ago, the sun has been sending to it as much heat energy as could be supplied by engines of 1.5 horsepower placed on each square yard of the earth's surface. Whatever the source of all this energy, the sun has been losing 4,630,000 tons in weight every second of this long interval of the earth's existence. Yet, in nearly 2,000,000,000 years, it has lost only one pound out of every 7,500 pounds of its former weight. This means that the sun now weighs 2,188,000,000,000,000,000,000,000,000 tons and that in a little less than 2,000,000,000 years it has lost only 291,700,000,000,000,000,000,000 tons! In spite of this loss, the sun that is now supporting all forms of life on the earth is essentially the same sun, both in mass and in brightness, as the primordial earth beheld nearly 2,000,000,000 years ago.

It is quite impossible to imagine the magnitudes of the quantities represented by these numbers; and we are by no means consoled when we are asked by the modern astronomer to think of a star, such as S Doradus, giving out a half million times more heat and light than would the sun if placed at the same distance. This means that in weight, also, this star is decreasing one-half million times more rapidly than the sun; in other words, it loses in one second about 2,300,000,000,000 tons of light and heat. Bewildering though these figures may appear, they are none the less real. They have the support of actual measurements. Furthermore, there seems to be no escape from the conclusion that the sun—although approximately an average star—can at best afford only a very feeble comparison with some of the other far-away suns in actual brightness. In fact, in 1885 a star appeared in the constellation of Andromeda which was even more luminous than S Doradus and was proportionately more brilliant than the sun. Stars of this type, however, are abnormal; and their lives of lavish dissipation are short. They are apparently huge celestial conflagrations, and in most cases a few days suffice for them to adjust themselves to more moderate outputs of energy.

The materials of which the stars are built are much the same as those entering into the earth's constituency. In fact, man has not been able to find a single element in the stars with which he is not now familiar; and he is ever on the alert with the spectroscope examining stellar atmospheres to determine not only what elements are present but also how much of each element is to be found. With matter, however, the stars apparently are able to do at least one miracle not yet understood by man. Were man able to transform even one ounce of matter into energy, his power problems would be solved. The stars, on the other hand, evidently do this harmoniously without one iota of the intelligence of man. Man has been on the earth only about one million years, and in comparison with the earth and the stars he is yet an infant—perhaps too young to play with so much fire, for Mother Earth would not be a safe abode for one who could accomplish this feat of the stars.

Not only are the stars able to derive this huge output of energy from their interiors in a way not yet familiar to man, but they are also able to adjust the outward flow of energy so that their spans of life are much more uniform than the "three score and ten" proverbially allotted to man. This interpretation follows from the so-called mass-luminosity relation discovered by Sir Arthur Eddington. From this relation the mass of a star is known with some degree of precision once its intrinsic luminosity is known. More explicitly, the more luminous the star the more massive it is. In other words, the stars of great intrinsic brightness and great

mass in a given time interval radiate away into space a greater percentage of their masses than do the less massive ones; a star with ten times the mass of the sun will decrease to half its present mass in a much shorter time than will the sun, and similarly the sun will decrease in mass to one half its present value in a much shorter time than will a star having a mass one tenth that of the sun. Strictly speaking, the mass-luminosity relation is one between mass and the rate at which the mass is decreasing.

The mass-luminosity relation lends itself more readily to a mathematical analysis when given in the form,

$$m = 1.83e^{-0.17M} + 2.17e^{-0.56M} \qquad (1)$$

Here m is the mass, M is the "absolute magnitude" and a measure of the intrinsic luminosity, and e is the base of natural logarithms—about 2.718. This equation can make no claim to any higher degree of accuracy than the mass-luminosity relation itself, but within the limits between which masses and intrinsic luminosities of the stars are known the agreement is remarkably close.

The relation of intrinsic luminosity to mass is illustrated in Fig. 1, whence it is seen that the range in intrinsic brightness among the stars is very much wider than in mass. Although at its maximum S Andromedae, the bright nova which appeared in the nebula in 1885, was much more luminous than 100,000,000 suns such as ours, it is doubtful if its mass is as much as 50 times that of the sun; it is certainly less than the value computed by equation (1). Indeed, those stars which have masses as great as 100 times that of the sun seem to be relatively quite rare. Such may not be the case, however, for the stars of small mass. Very probably these are much more numerous than the observational evidence would indicate. According to the mass-luminosity relation, such stars are also

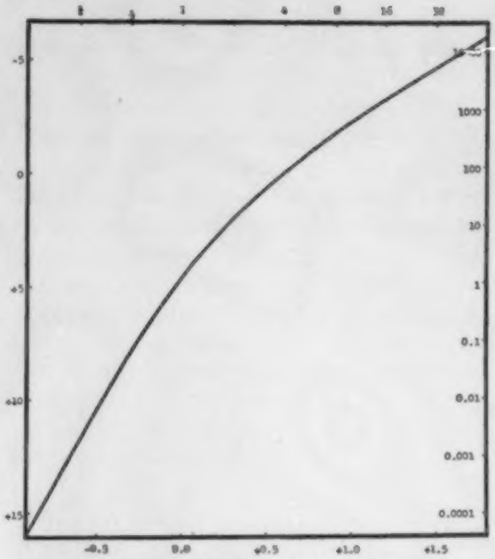


FIG. 1. THE MASS LUMINOSITY RELATION

THE SCALE OF THE ABSCISSAE IS A LOGARITHMIC ONE, VALUES OF LOG M BEING WRITTEN AT THE BOTTOM AND THOSE OF THE MASS M AT THE TOP OF THE FIGURE. ORDINATES AT THE LEFT HAVE THE SCALE OF ABSOLUTE MAGNITUDE, AND AT THE RIGHT ARE THOSE OF LUMINOSITY IN TERMS OF THE SUN'S LUMINOSITY. (DATA ARE FROM RUSSELL, DUGAN AND STEWART, *Astronomy*, VOL. 2, P. 691.)

of small intrinsic brightness and have little chance of being discovered. Although of all the fixed stars Proxima Centauri rivals α Centauri for the place of closest proximity to the earth, it is so feeble in intrinsic luminosity that it can not be seen without the use of the telescope; and ordinarily astronomers do not attempt to measure the distances and intrinsic luminosities of stars so faint unless evidence of close proximity is indicated by a relatively high proper motion with reference to the other stars. Yet one star, Ross 248, has been discovered which apparently gives less light than Proxima Centauri. No less than 30,000 stars such as Ross 248 would be required to give as much light as our own sun if both could be observed at equal

distances from the earth; but, according to the mass-luminosity relation, its mass should not be much less than $\frac{1}{9}$ that of the sun. In comparison with S Andromedae, therefore, the known range in intrinsic luminosity is approximately 3,000,000,000,000 times, while in mass the heaviest of the stars probably is not greatly in excess of 1,000 times that of the smallest. Stars very much less massive than $\frac{1}{9}$ that of the sun, if they exist, would be so feeble in light-giving power that their masses should remain appreciably constant almost indefinitely. Indeed, the following discussions seem to warrant the conclusion that from radiation alone the time interval required for a star to decrease from a value comparable to that of the sun to $\frac{1}{9}$ of that value is 25 times as long as is required to decrease from 100 times the mass of the sun to its present value.

If the changes in a star's mass are due only to losses in radiation, the time interval required for it to decrease from infinite mass to a mass m corresponding to an absolute magnitude of M is, in years,

$$T = 1.72 \cdot 10^{11} \int_{m}^{\infty} e^{0.921M} \partial m \qquad (2)$$

This equation follows from the relativity relation between mass and energy and from the fact that the luminosity L in the equation, $M = 4.85 - 2.5 \log L$, is the rate of change of the energy E with respect to time. Since the sun's luminosity is taken as unity, its absolute magnitude by the last equation is $M = +4.85$.

As applied to the older stars, the results which follow from equation (2) are little affected if the ideal condition of infinite mass is replaced by an assumption of an initial value of 100 times that of the sun, say. For stars having masses above this value, the radiation is almost explosive in character—that is, provided such stars conform to the mass-luminosity relation of equation (1). On the other hand, it has been suggested that the gravitational pull resulting from such a large mass might be so large as to offset the enormous pressure of the outgoing radiation and to prevent the escape of light, making them invisible.

From equations (1) and (2) it can now be shown that the time, in years, required for a star to decrease from an infinite mass to a mass m, corresponding to an absolute magnitude M, is

$$T = 7.125 \cdot 10^{10} \; e^{0.751M} + 5.791 \cdot 10^{23} \; e^{0.861M} \qquad (3)$$

The ages of stars of different absolute magnitudes M and masses m computed by means of this equation are given in Table I, and the results are illustrated graphically in Figs. 2 and 3. Similar results have also been obtained by other investigators. As an upper limit to the age of the sun, a period of $6.13 \cdot 10^{12}$—or 6,130,000,000,000—years is found for the time required for it to shrink from an infinite mass to its present value. Had its initial mass been only 100 times its present value ($2.19 \cdot 10^{27}$ tons), the calculated age of the sun would be rather $6.08 \cdot 10^{12}$ years. In other words, its age has only been shortened by 51,500,000,000 years, which is the time required for a star to shrink from infinite mass to one of 100 times that of the sun, according to the calculations. Such a decrease in mass in so short a time as 51,500,000,000 years is, cosmically speaking, almost explosive in character. As opposed to the view that the very heavy stars might have a gravitational field so strong as to prevent the escape of matter (or of energy) moving with the velocity of light, it can be shown in passing that the mass of such a star should be about 480 times the radius, when the mass and the radius of the sun are taken as standards; and this fact fails to harmonize with observations. The ratio of mass to radius for the

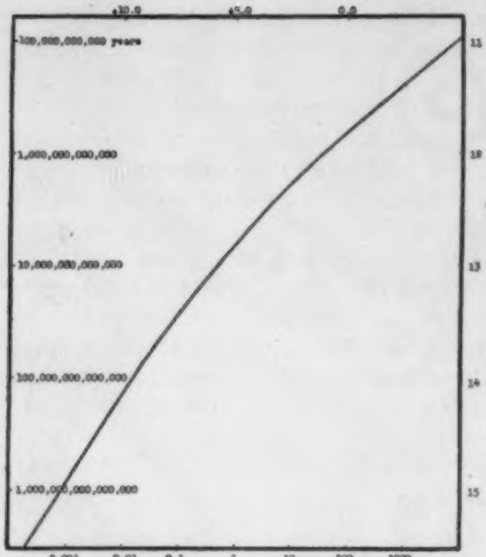


FIG. 2. THE AGES OF STARS OF DIFFERENT LUMINOSITIES

AT THE BOTTOM THE ABSCISSAE ARE INTRINSIC BRIGHTNESSES IN TERMS OF THE SUN'S BRIGHTNESS AND AT THE TOP ARE ABSOLUTE MAGNITUDES. THE ORDINATES AT THE LEFT ARE AGES IN YEARS AND AT THE RIGHT ARE LOGARITHMS OF THE AGES.

sun, for example, is unity; and among the other stars, this ratio decreases very rapidly with increasing masses. It is quite contrary to observation, therefore, to suppose so large a value of this ratio as 480 is to be found for very large masses.

The fact must not here be lost sight of, however, that mathematics is an ideal science, and only under ideal conditions does its language conform to the truth. It is not that figures are inherently subject to error but rather that in shaping them to the necessary conditions and assumptions peculiar to the problem they may be made so by the imperfections of the human technique. Some of the assumptions made here, possibly subject to error, are: (1) the theory of relativity is applicable. (2) There are no exceptions in any stage of stellar evolution to the mass-luminosity relation of equation (1). (3) The initial mass of a star is infinite. (4) No change in mass is admitted except through losses in radiation. (5) Astronomically speaking, there is no end to the radiation of mass. (6) No allowance is made for the possibility of a single star breaking up into two or more components or for other possible discontinuities in the equations.

As to the first of these assumptions, the only possibility of error seems to consist in denying the whole theory of relativity, and modern science will not afford such a step at present. Whatever the source of all the energy which the stars pour out, the theory maintains that the expenditure of energy must always be attended by a corresponding decrease in mass. Light, which is a form of energy exerting a pressure—although very slight—upon all surfaces on which it impinges, must also have mass and weight according to the theory; and when light is emitted, weight is therefore lost by the source.

Although it is tacitly assumed that the relation between mass and luminosity is accurately specified by equation (1), the evidence seems to be against so strict a correlation as a one-to-one correspondence. For example, the most accurate measurements of the absolute magnitude of the sun indicate a value $M = +4.85$ for which equation (1) predicts a mass, $m = 0.95$, instead of the standard value of unity. It is quite probable, however, that at least a part of the divergencies from the mass-luminosity relation is due to inaccuracies of measurements; and in any case, admitting some small deviations, the results to which equation (1) leads seem to be good approximations. At least this is true over the known range of star masses, which extends from about one fifth to a few hundred times the sun's mass; and it is only to this range that the mass-luminosity relation is applicable with any confidence. On

the other hand, stars with gravitational fields sufficiently strong as to prevent the escape of radiation—if indeed such should exist—are also outside the range of the present discussion, forasmuch as they do not conform to the predictions of equation (1).

It has already been shown that the assumption of an initial mass of 100 times the sun's mass subtracts only about 51,500,000,000 years from the figures given in Table I, which has been calculated with the assumption of an infinite mass initially; and for the older stars so short a period as 51,500,000,000 years is quite negligible, astronomically speaking. It is better perhaps to define here the "age of a star" as the time required to decrease continuously from an initial mass of infinity to a present value, without any gain or loss to outside sources, except through radiation. Such a definition is found also to satisfy other objectionable features which follow. As will be seen later, the fact that the very bright (and therefore the very massive) stars are quite infrequent is itself sufficient evidence that the time interval represented by the earlier stages of evolution in a star's life must be relatively quite short. What precedes the stellar stage astronomers are yet not unanimously agreed; perhaps the best tentative suggestion is that the nebulous wisps shown in Fig. 4 eventually condense into one or more stars. At least, such nebulosities, which for the most part are found in or near the Milky Way, are as yet in a state quite rarefied and shine only by the light from other stars in their neighborhood — conditions which presumably might precede a stellar state.

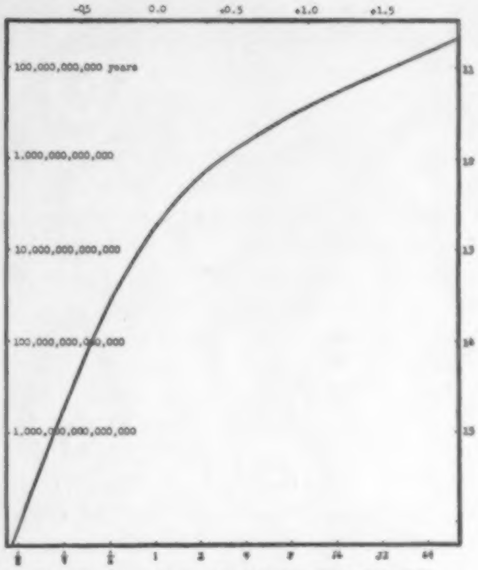


FIG. 3. THE AGES OF STARS OF DIFFERENT MASSES

AT THE BOTTOM THE ABSCISSAE ARE MASSES IN TERMS OF THE SUN'S MASS AND AT THE TOP ARE LOGARITHMS OF THE MASS. THE ORDINATES AT THE LEFT ARE THE AGES IN YEARS AND AT THE RIGHT ARE THE CORRESPONDING LOGARITHMS OF THE AGES.

The fourth of the above assumptions, the supposition that a star does not

TABLE I

M	L	m mass	log m	T Age in years	log T
− 5	 8710	40.0	+ 1.60	96,900,000,000	10.986
− 4	 3470	24.0	+ 1.38	140,000,000,000	11.147
− 3	 1380	14.7	+ 1.17	204,000,000,000	11.309
− 2	 550	9.2	+ 0.96	297,000,000,000	11.473
− 1	 219	6.0	+ 0.78	437,000,000,000	11.641
0	...... 87.1	4.0	+ 0.60	650,000,000,000	11.813
+ 1	...... 34.7	2.8	+ 0.44	982,000,000,000	11.992
+ 2	...... 13.8	2.0	+ 0.30	1,510,000,000,000	12.180
+ 3	...... 5.5	1.5	+ 0.18	2,390,000,000,000	12.378
+ 4	...... 2.2	1.2	+ 0.06	3,890,000,000,000	12.590
+ 5	...... 0.87	0.91	− 0.04	6,560,000,000,000	12.817
+ 6	...... 0.35	0.74	− 0.13	11,500,000,000,000	13.061
+ 7	...... 0.14	0.60	− 0.22	20,900,000,000,000	13.320
+ 8	...... 0.055	0.49	− 0.31	39,400,000,000,000	13.595
+ 9	...... 0.022	0.41	− 0.39	76,300,000,000,000	13.883
+10.0	...... 0.0087	0.34	− 0.47	152,000,000,000,000	14.180
+12.5	...... 0.00087	0.22	− 0.66	903,000,000,000,000	14.956
+15.0	...... 0.000087	0.14	− 0.84	5,690,000,000,000,000	15.755

suffer any change in mass except by radiation, very probably is not substantiated by the facts. Although most meteors in passing through the upper layers of the earth's atmosphere apparently are burned up, their ashes undoubtedly fall to the earth; and the mass of the earth, from this source, must be slowly increasing. This increase of mass would be much more pronounced in the case of the sun and the stars, for the reason that their gravitational pull on outside bodies (such as meteors) would be much stronger than that of the earth, since their masses are larger than that of the earth. On the other hand, the sun, and probably likewise the stars, seems to be slowly losing mass in the form of atoms and electrons, thus probably accounting for the aurora borealis, or the "northern lights." Expanding shells of nebulous gas are also observed surrounding some of the bright novae, and the fact that these "temporary stars" very suddenly rise to brightnesses of 100 times their normal values suggests some sort of an explosion whereby some part of their masses are lost. The frequency with which these apparent conflagrations occur further suggests that in the calculated lifetimes of the stars such phenomena are by no means uncommon. There is some possibility, on the other hand, that mass may be gained from the same source to which a superficial explosion of this type may be due—that is, assuming that such a star owes its explosion to an encounter with a planet or nebulosities which it may also add to its own mass. On the whole, therefore, it seems reasonable to suppose that, aside from the mass lost by radiation, the mass gained may counteract that lost—such as in the form of atoms, of positrons and electrons, either by explosions, or even by the genesis of planets similar to those, including the earth, which revolve periodically around the sun.

In calculating the ages of the stars, graphically illustrated in Figs. 2 and 3, it is tacitly assumed that a star having a mass of 100 or 10 times that of the sun may continually, and continuously, radiate mass until it is much less massive than the sun. The mass-luminosity relation itself argues against the existence of stars with appreciable masses but without active material which can be transformed into radiation. If only a part of the material of which a star is constituted should be transformable, the luminosity of the star would no longer conform to the mass-luminosity relation, when its energy stores became somewhat depleted and when the star began to fade.

Of the six possibilities that the ages given in Table I may not represent fairly good approximations to actual facts, the last may perhaps lead to the most serious differences. Although the process of fission involves the loss of mass other than by radiation, this process apparently merits special attention for the reason that it may be one which is actually taking place among the stars; and it may affect the calculations considerably. According to Fig. 3, the ages of the stars for masses greater than about four times the sun's mass should be decreased by about 40 per cent. when the mass is halved; and the fact that the representation for smaller masses begins to depart considerably from the initial straight line indicates that for these stars an amount in excess of 40 per cent. and increasing with decreasing mass until a uniform amount of more than 10 times must be subtracted from the ages, when the mass is halved. In other words, loss of mass by fission always makes the calculated ages too large, the percentage of error increasing with increasing age and decreasing mass. Furthermore, when the two stars resulting from fission are not equal in mass, the percentage of error in the fifth column of Table I decreases with increasing differences between the two components. This is evident from

the fact that the hypothetical error is zero when one component contains all the mass.

These discussions seem to be more eloquently justified by the observed fact that, among the brighter ones at least, one star out of every three or four can be resolved into two or more components. In some cases the components are far enough apart as to be resolvable by the telescope; but representatives of another class, quite distinct from the visual doubles, are identified by means of the spectroscope or by periodic eclipses. These, the spectroscopic binaries and the eclipsing stars, are distinguished by the fact that their components are much closer together and, in some cases, almost in actual contact. Spectroscopic binaries are eclipsing when the planes of revolution are so oriented that one star passes between the earth and the other and thus partially intercepts its light. If all the stars are decreasing in mass and in heat content, the question then arises as to the progenitors of this class of very close doubles. In this connection, the only class of stars which has hitherto demanded any attention is the Cepheid variables. Although the luminosities of these stars apparently rise and fall with periods similar to those of eclipsing binaries, there are few astronomers who believe that they are actually double.

The most generally accepted opinion as to the causes underlying the variations of Cepheids seems to be that they are really variable in size; or, in other words, they are pulsating. Although this theory—the pulsation theory—claims the support of such well-known astronomers as Shapley and Eddington, there is a minority of others who believe that Cepheids represent a stage in the lives of these stars preceding fission. This theory, of which Jeans is perhaps the ablest champion, is that their shapes are similar to that of a dumb-bell and that they owe their variations to rotations of such peculiar figures about the smaller axes. By secular condensations about the two nuclei of the dumb-bell shaped figure, Jeans believes that the components of a binary system are eventual consequences. Both the pulsation and the fission theory, therefore, admit that the evidence is decidedly against any conjecture of actual duplicity of these stars; and the fission theory seeks also to explain the origin of the close binaries, an undertaking not attempted by the pulsation theory. Some reasons for believing that these stars actually are in the act of dividing into binary systems are: (1) The spectroscopic evidence points rather to rotation than to pulsation. (2) The mean densities which can be computed are approximately what would be expected of an embryo binary system where the components have not yet separated. (3) The mean radii of Cepheids compare favorably with the separation of the components of binary systems with similar periods. (4) Slight evidences of correlations of colors and brightnesses of short-period binary systems with Cepheids are to be found. (5) The galactic distribution of the two classes of objects compare favorably. (6) The agreement of periods is as good as could be expected. Illustrations of the possible transitional stages and a somewhat fuller discussion of related problems are to be found in an article on "Variable Stars" by the writer in the Annual Report of the Smithsonian Institution for 1932, pages 121–131.

If there are stars which are in the act of dividing, as there are some reasons for believing, the course is to decrease the net output of radiant energy of the universe as a whole. This follows from the fact that the combined flux of energy from both the new stars resulting from fission is less than that of the parent star before fission took place. The evidence seems to favor the conclusion that only the brighter and the more massive stars

can ever break up, if indeed division ever does actually occur. Cepheids are rarely, if ever, less than 100 times as bright as the sun; and from this fact it may be supposed that no fission ever occurs among those stars whose luminosities are less than 100 times that of the sun or whose masses, by the mass-luminosity relation, are less than four times the sun's mass. It is perhaps of some significance to note that in Figs. 2 and 3 sharp deviations from what would otherwise be straight lines occur for luminosities and masses slightly below the above values. In case a star of four times the sun's mass, having a luminosity of 100 suns, should break up into two stars, each having twice the sun's mass, each of the components should give only as much light as 14 suns such as ours. In other words, the light-giving power of the parent star has now fallen from 100 times to 28 times the sun's luminosity after fission has taken place. If the two new stars resulting from fission are of unequal mass, the combined light will be more than 28 times but certainly less than 100 times the sun's brightness if there is no violation of the mass-luminosity relation. In any case, therefore, the result is to conserve the lavish output of energy by the stars in general. If this energy radiated away into space is actually lost, nature has here a means of checking these leakages of the universe.

When the age of the earth is estimated to be more than 2,000,000,000 years, it is also understood that this figure carries all the weight generally attributed to actual observations. The presence of radioactive elements and their products in certain definite ratios found among the older rocks of the earth's crust constitutes an increasing wealth of circumstantial evidence as to the ages of these rocks when these evidences are weighed against laboratory measurements of the rate at which the parent elements are decomposed; and the observations apparently justify the conclusion that there was a time much farther back than 2,000,000,000 years when the earth was in a molten state.

From the stars, however, such direct and eloquent testimony is not yet available. The only messages man ever receives from these far-away suns are bound up in very limited quantities of light which his instruments intercept; and he is asked to decipher and to learn their codes. Meager as these may seem, they bear testimony of the constituency of the atmospheres of these stars, of their motions in the line of sight, of their temperatures, of their sizes, of their densities, of their masses, of their intrinsic luminosities and distances; in short, the beams of light which the astronomer collects and analyzes reveal to him the general physical conditions which exist in stars so far away that the light he studies may itself be hundreds of years old. On the other hand, man has been on the earth only about one million years; and in this interval of time he has about the same chance of observing secular changes among the stars as a genus of insects with a current life of one second would of predicting the changes and the span of life of any individual of the genus *Homo sapiens*. It is necessary to assume further that only in the last 0.0001 part of this second has this hypothetical insect been gifted with the ability to make reliable observations for at most can man claim detailed observations of the stars over a period of only a century—about 0.0001 part of his terrestrial existence. In this short interval of time he has assured himself that the stars have enormous supplies of energy, the output of which he is able to measure. If he can rely on the theory of relativity, as he believes he can, he can further specify just how many tons of light a star radiates in one second and compare this amount with the total mass of the

star. These are about the limits of his observations in attempting to measure the ages of the stars, and from data such as this Table I has been constructed. The time intervals here between successive magnitudes, however, undoubtedly carry considerable weight, at least much more than the absolute time values themselves.

If ramifications of the problem are to be relied upon for further clues of evidence, star counts should perhaps afford some cause for optimism. It is then necessary to assume a homogeneous aggregate of stars, sufficiently large, and that among these the birth rate is fairly uniform over such eons of time as are indicated here. Under these conditions, the number of stars between successive intervals of absolute magnitude should be proportional to the corresponding intervals of time required for a star to undergo the stages in its evolution represented by such magnitude differences. Thus in Table I about 43,000,000,000 years elapse between absolute magnitudes of -5 and -4 and about 64,000,000,000 years between magnitudes -4 and -3. Accurate star counts, therefore, should reveal about 43 stars between absolute magnitudes -5 and -4 to 64 between -4 and -3. Counts by Seares at Mount Wilson indicate for the brighter stars much more rapid increases in numbers with decreasing brightness than is to be inferred from Table I, but for the fainter ones the increase in numbers is much slower than is specified by Table I. Among the stars which are intrinsically faint such stationary or abrupt falls in numbers, for successive intervals of decreasing brightness, might be understood to represent an upper limit to the age of the group from which the counts are made. The question of homogeneity and other factors of uncertainty, however, are not to be lost sight of here; and, under all the conditions here implied, it is an open question as to how far actual star counts might be expected to agree with successive time intervals of Table I. More ideal counts could certainly be made from such star groups as the Magellanic Clouds of the Southern sky or perhaps from some of the nearer loose clusters.

One further question, without some consideration of which the present discussion can hardly be regarded as complete, takes cognizance of the extravagant flow of light and heat away from the stars into the realms of unfathomed space. It is estimated that in the Milky Way system there are about 50,000,000,000 stars and that the sun in energy output is little, if any, above the average. Consequently, if the sun loses 46,000,000 tons of heat and light every second, that lost by the whole system over the eons of time indicated in Table I is almost beyond the bounds of comprehension. At least, unless indeed nature is in some way rewinding it, the day will come when the universe will be no more than a great cemetery of worn-out suns whose last vestiges of ancient glories have forever faded.

If the calculations made here mean anything, there seems to be no escape from the conclusion that an intelligent being, gifted with equipment perhaps much more advanced than that of the present day, say 20,000,000,000,000,000 years hence, would probably see less than a dozen of the magnificent stars now visible to terrestrial man. At this distant date, not one of the luminous giants now lighting the nocturnal sky would have a mass as large as one tenth of the sun's present mass; and of these no less than 100,000 would be required to radiate as much light and heat as the sun now radiates. If, on the other hand, the universe is rewinding itself and new stars are yet being born, then in attempting to portray what our future astronomers would observe, situated perhaps on some far-away planet yet un-

Courtesy of Harvard College Observatory

FIG. 4. NEBULAE ABOUT η CARINAE

PHOTOGRAPHED WITH A 24-INCH BRUCE TELESCOPE AT THE BOYDEN STATION OF HARVARD COLLEGE OBSERVATORY IN SOUTH AFRICA. EXPOSURE 80 MINUTES.

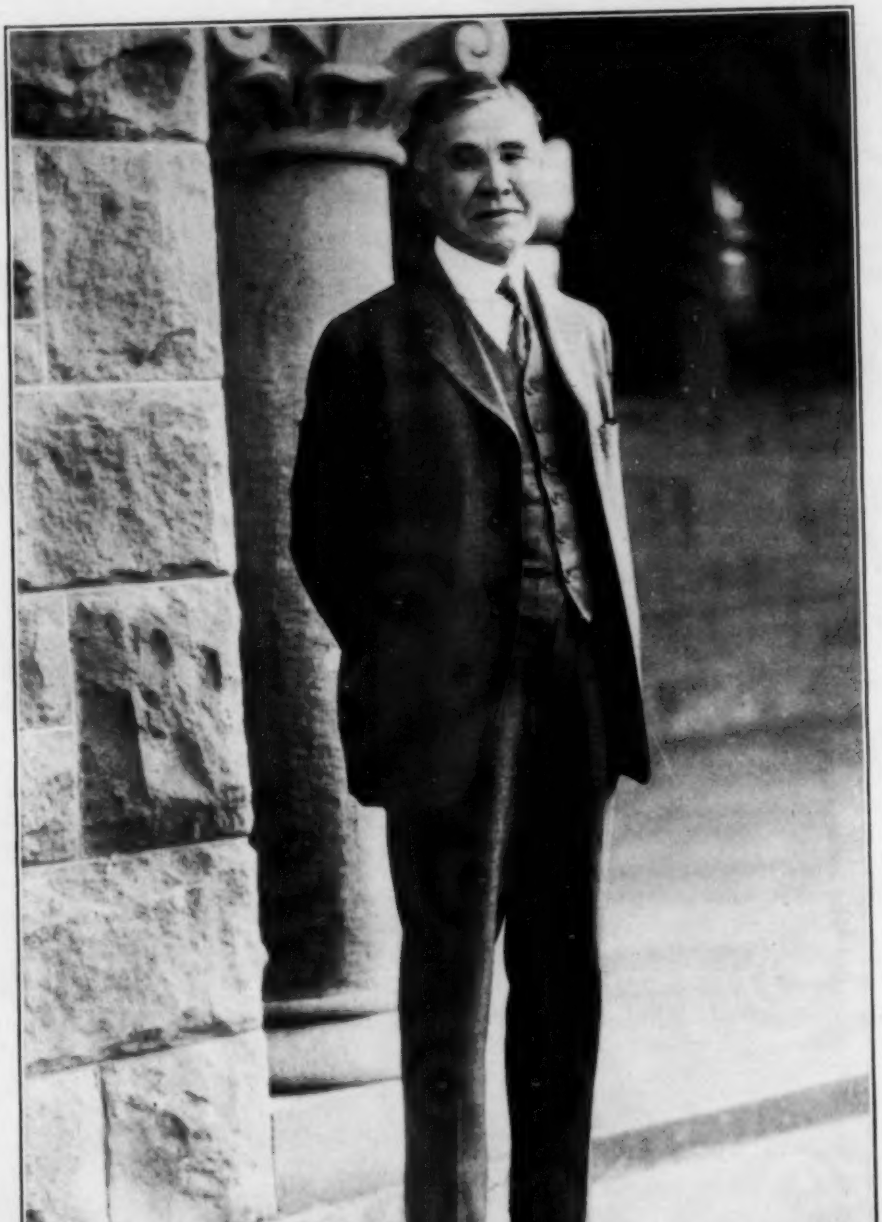
born, we should have more cause for optimism.

The question yet remains, however, as to whether or not the universe is actually running down; and on this problem researches now in progress will probably paint a much clearer picture within the next few years. Investigations conducted by Anderson at the California Institute of Technology seem to support the view that positively charged positrons and the negative electrons, both very minute and ultimate particles of matter, are produced in pairs from the energy of the very short γ rays when they impinge on a material surface. If such is indeed the case—and there seems to be no room for doubt—and if light and heat from the stars represent the apparent transmutation of matter into energy, then science seems assured that the interaction between matter and en-

ergy is a reversible one; that is, energy may be transformed into matter as well as matter into energy. Furthermore, the old theory, that both the mass and the energy content of a system are forever absolutely fixed, now takes on a new and a wider meaning. It denies that either the mass or the energy of a body is absolutely invariable; rather it is the content $E + mc^2$ that is constant.

Further inquiry yet arises, first, as to whether rays of light from the stars act in the same manner as the very short γ-rays and, second, as to whether the energy content of these rays necessarily require the presence of a material agent before this energy can be transformed back into matter. Neither question can be definitely answered at present; but a tentative conjecture that the only difference in effect between the longer rays of starlight and the γ-rays is a quantitative one is probably not far wrong. Moreover, the astronomer is also sure that, in certain directions at least, the depths of space are filled with great clouds of very tenuous gases; and it may be that the starlight captured by these clouds is reconverted into matter, thus adding to the material content of these clouds which eventually may develop into many stars. Such a cloud, illuminated by light from the associated stars and so great in extent that years are probably required for light (moving with a speed of 186,320 miles per second) to transverse it, is illustrated in Fig. 4. If matter is transformed into energy in the hot interiors of the stars, what contrast more fitting for the transformation of energy into matter could be sought than these frigid realms of unfathomable space? The ideal philosophy apparently demands an eternal universe susceptible neither to death nor to decay, but science is yet confronted with the challenge as to the destiny of all the energy from the stars not intercepted by the material universe.

The fate of terrestrial man and his earthly abode, however, can hardly contemplate the lapse of such eons of time as the 20,000,000,000,000,000 years mentioned above. Man is firmly convinced that any given form of matter is quite ephemeral; there is no state of the universe nor of any of its parts that is eternal and everlasting. The frequency of novae, like S Andromedae and the many others which blaze up from time to time, suggests that in the course of the life of every star such conflagrations are by no means uncommon. This point is not overemphasized when it is predicted, therefore, that long before the sun shall have been turned into darkness by age and the flight of time, it and all "the heavenly bodies shall be dissolved with intense heat, and the earth and all the works that are therein shall be burned."



EDWARD CURTIS FRANKLIN

THE PROGRESS OF SCIENCE

EDWARD CURTIS FRANKLIN, 1862–1937

With the passing of Edward Curtis Franklin on February 13 one of the great personalities of this generation in chemistry in America has gone. Few men whom one meets in an entire lifetime, within or without academic circles, have lived a life so full of adventure and fine friendships, and adorned by a personality of such singular simplicity and charm and a record of such outstanding achievement.

If he had lived another fortnight he would have reached the age of seventy-five. He was born in Geary City, Kansas, on March 1, 1862, the eldest son of Thomas Henry Franklin, a Philadelphian who went West in 1857, erected a sawmill and made lumber from the abundant growth of elm, oak and walnut on the bottoms of the Missouri River. Here he spent his boyhood, fished and swam in the sloughs and river, roamed the hills and river bluffs and learned to hunt and trap wild game. He and his younger brother, Will, who had a notable career as a physicist, revealed their scientific bent in early youth, making Leyden jars and batteries, experimenting with chemicals in a corner of the sawmill office, having unending amusement out of a James Quenn microscope bought for them by their father, and collecting crinoids and other fossils from the limestone bluff along the river. Later on they erected a telegraph line two miles long and became quite expert in sending and receiving by the Morse Code. With the help of their father they made a pair of Bell telephones from directions they found about 1877 in the Scientific Monthly, then published as the *Popular Science Monthly*. These were used on the telegraph line and later on a line from their home to the sawmill. The telephone invented by Alexander Graham Bell was first exhibited at the Centennial Exposition in 1876, and it is interesting that these two young enthusiasts, both under fifteen, had a crude reproduction working out in Kansas a year or so later.

Entering the University of Kansas in 1884 at the age of twenty-two, he graduated as a major student in chemistry, and two years later went abroad with his brother for a year of graduate work—he to work in chemistry, his brother in physics. They were not oversupplied with funds but had read shortly before about how to do Europe on fifty cents a day and felt that if any one could do it they could. Afoot and by train and Rhine boats they crossed Germany to Switzerland, climbed some of the great peaks of the Alps and made their way back to Berlin. Here Professor Franklin worked for a year in Tiemann's laboratory and attended lectures by von Hofmann on general and organic chemistry chiefly to learn the lecture technique of that great teacher, by Helmholtz, Kundt and Max Planck. Returning to the University of Kansas he taught for two years, then went to Johns Hopkins to work especially with Professor Remsen, where he received the doctorate in 1894. The offer of an associate professorship lured him back to Kansas, but two years later, not yet sure that he should follow an academic career, he accepted a position as chemist and co-manager of a gold mine and mill in Costa Rica. The following year he returned to the University of Kansas, where in 1898 he was advanced to a full professorship, and remained until he went to Stanford in 1903. Except for an absence of two years, on leave of absence from 1911–13 as chief of the division of chemistry of the Public Health Service in Washington, he remained continuously in active service at Stanford until his retirement as professor emeritus in 1929.

Many distinguished honors came to him in later life—among them honorary degrees from Northwestern, Western Reserve and Wittenberg, the Nichols Medal, the Willard Gibbs Medal, the presidency of the American Chemical Society, the invitation to South Africa in 1929 as the honorary guest of the British Association for the Advancement of Science and election to the National Academy of Sciences and the American Philosophical Society.

Outside of his work of teaching and research, nothing contributed more to the joy of living nor stored his mind with happier memories than his love of an outdoor life. He was especially fond of mountain climbing, camping, fishing and hunting, and, in later years, of motoring. I have rarely seen any one so skilful at putting a diamond cinch and a well-balanced pack on a stubborn packmule. A part of nearly every summer for many years was spent in the mountains of Colorado and California, most of whose great peaks were climbed by him. Among these are a number over fourteen thousand feet and a score or more around thirteen thousand. One of the notable trips in the long record of summer excursions to which he often referred was in the summer of 1889 when for nearly three months he was in the Colorado "Rockies" with a party from the University of Kansas, including Chancellor Snow, Will Franklin, Vernon Kellogg, Frederic Funston, Hubert Hadley, William Allen White and a few others. They camped and packed through the wilder regions, climbed many lofty peaks, explored new country and had many thrilling adventures. That was a great company of young men, nearly all of whom became nationally known in later years. The lure of great mountains never left Professor Franklin, even after he had reached the age when such extreme physical exertions are hazardous. In 1929, at the age of sixty-seven, returning from South Africa along the east coast, he got within about thirty miles of Mt. Kilimanjaro, which rears its majestic summit nineteen thousand feet—a sight to stir the emotions of every true mountaineer.

Since the summer of 1931, on four extended transcontinental tours by automobile, he traveled a distance more than equal to twice around the globe. His last trip, made alone last autumn, took him eastward to the Atlantic Coast, southward to the southernmost tip of Florida and westward through the South, lecturing before many of the sectional groups of the American Chemical Society, and covering over thirteen thousand miles—at 74!

The scientific work of Professor Franklin dealt mainly with what is now known as the ammonia system of acids, bases and salts. This was begun at the University of Kansas and was continued throughout the ensuing three decades which he spent at Stanford. It led not only to the synthesis of a large number of compounds new to science by him and his coworkers, but to new concepts of fundamental importance in regard to the structure and relationships of many nitrogenous compounds out of which has grown a new system of compounds in chemistry. His investigations in this field, embodied in a large number of important papers and a recent monograph, will stand as one of the major contributions to the chemistry of this period.

No review of the career of Professor Franklin would be complete without reference to his ability as a teacher. His lectures were models of direct, orderly, clear, precise thinking, and were made peculiarly effective by many experimental demonstrations. Here he was at his best! His native resourcefulness and ingenuity and mechanical skill were a constant source of admiration to all who came under his instruction in the classroom or research laboratory. Most of the very complicated and delicate glass apparatus which had to be developed to meet the experimental conditions in working with liquid ammonia were made

by his own hands. They are fine examples of the glass-blowing art.

After the mantle of a professor emeritus fell to him he retained his office and private laboratory in the chemistry building. Here he continued his work and through the open door students and friends, old and new, went for a word of greeting or for an interesting discussion over a wide range of topics. A pleasant chat with him, or a bit of banter, which he enjoyed so much, was a source of good cheer which will be missed by all who have had the privilege of frequent contact with him. There was a delightful informality about him which was wholesome, friendly, even playful and always sincere. It is little wonder that he had so many loyal and intimate friends—for friends flocked to him like iron filings to a magnet. They, too, meant much to him. An evening in a congenial company, anywhere, was an unfailing source of pleasure to him. And whether around a Sierra campfire or in the carefree company of the club or about his own fireside, he was always the same delightful and stimulating companion whose alert and inquiring mind was constantly seeking to satisfy its zeal for new impressions and ready to draw upon those which had been stored away through a remarkably eventful and varied and fruitful career.

His was truly an abundant life—full, to a fine old age, of adventure, of an enduring love of nature, of lasting friendships and of the fruits of a surpassing career in teaching and research.

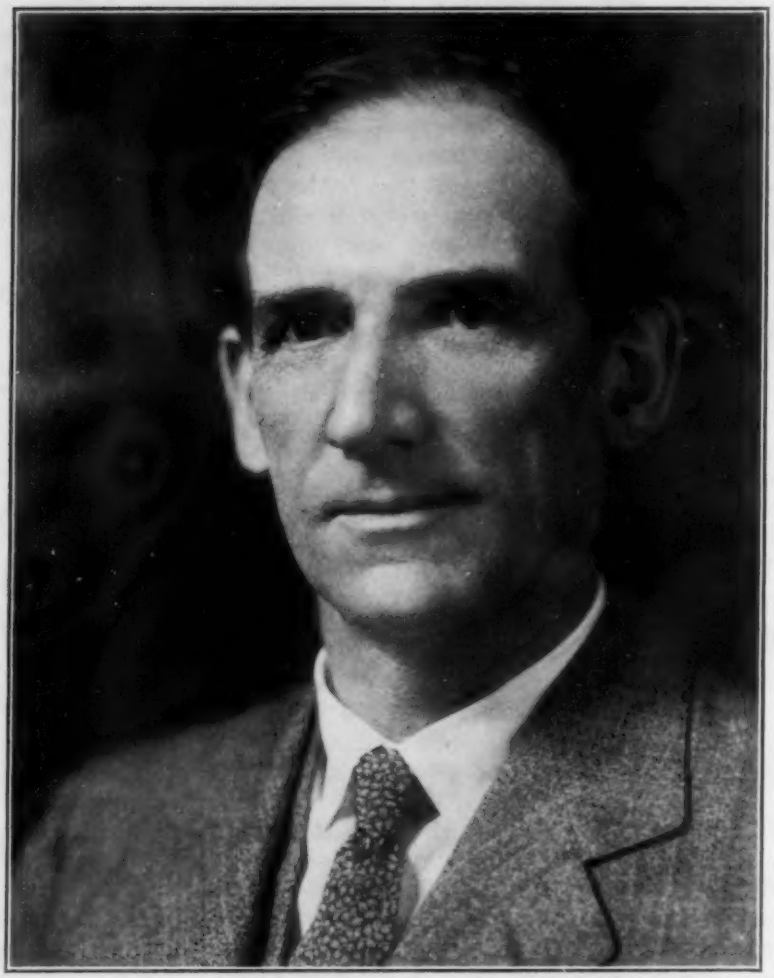
Robert E. Swain
Stanford University

DR. COTTRELL, RECIPIENT OF THE WASHINGTON AWARD

The award for 1937 of the Washington Award Commission has been bestowed on Frederick Gardner Cottrell, of Washington, D. C., "for his social vision in dedicating to the perpetuation of research the rewards of his achievements in science and engineering."

John Watson Alvord, a Chicago sanitary engineer, established the Washington Award in 1916, with the idea that there should be some such means of recognizing outstanding engineers who render unusual service in promoting the public welfare. The award is administered by the Western Society of Engineers in cooperation with the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers. Seventeen men elected for the purpose compose the Award Commission. The award is made annually, providing the members of the commission agree on a deserving candidate, as an honor conferred on a prominent engineer by his fellows for accomplishments which preeminently promote the happiness, comfort and well-being of humanity. There have been several years when no award was made, and the preceding thirteen noted American engineers to receive it included representatives of many branches of engineering.

Dr. Cottrell has achieved much in his scientific career. He is perhaps best known for his invention and subsequent perfection of the precipitator which bears his name. This was first conceived as a means for taking sulfuric acid fumes out of the atmosphere in a manufacturing plant and received its first commercial trial in the important Riverside Cement Company's plant, where through its use the company was enabled to remain in business in the midst of an important citrus fruit area. The precipitator effectively removed an amount of dust, totaling tons per day, which up to that time had been distributed through the stack gases over a wide agricultural area, doing much damage. Since then there have been many installations of the Cottrell precipitator, the largest of these



DR. FREDERICK GARDNER COTTRELL

being at the smelter of the Anaconda Copper Company in Anaconda, Montana, which includes the largest smoke-stack in the world. An important by-product recovered from this installation is arsenic, so important in insecticides and fungicides. One of the newest problems solved with the precipitator is the recovery of fly ash in plants burning powdered coal. The physical character of this ash is such as to make it not only disagreeable but almost a menace if permitted to remain in the air.

Dr. Cottrell, widely known as a chemist and metallurgist, has served as director of the U. S. Bureau of Mines and director of the Fixed Nitrogen Research Laboratory of the U. S. Department of Agriculture. He is interested in all manner of scientific developments, and besides founding the Research Corporation has since organized Research Associates, Inc., of which he is the president. Dr. Cottrell has gone a step further than the majority of his colleagues in dedicating to science through the operations of the Research Corporation the principal part of the income from his patents. During the years this has run into several hundred thousand dollars, which might have

been his own personal reward for his achievements, had he not preferred to set it aside, as he has, that it might perpetuate research, be available to undertake the development of worth-while ideas of inventors who could not perfect their inventions and in general be used in the interests of public welfare.

To his colleagues Dr. Cottrell is known as a stimulating enthusiastic research worker. He has little interest in pecuniary rewards from such work and takes his greatest delight in seeing well done some piece of research that promises practical application and wide utilization with concurrent benefit to the people. His best friends may affectionately describe him as a butterfly chaser at times, and there must be some brilliantly hued butterflies to pursue when one is so interested in all that goes on. He is beloved of those who work with and associate with him, well informed in a multitude of diverse fields and a worthy representative of his profession for this or any other honor.

H. E. Howe

Journal of Industrial and Engineering Chemistry

THE 125TH ANNIVERSARY OF THE ACADEMY OF NATURAL SCIENCES

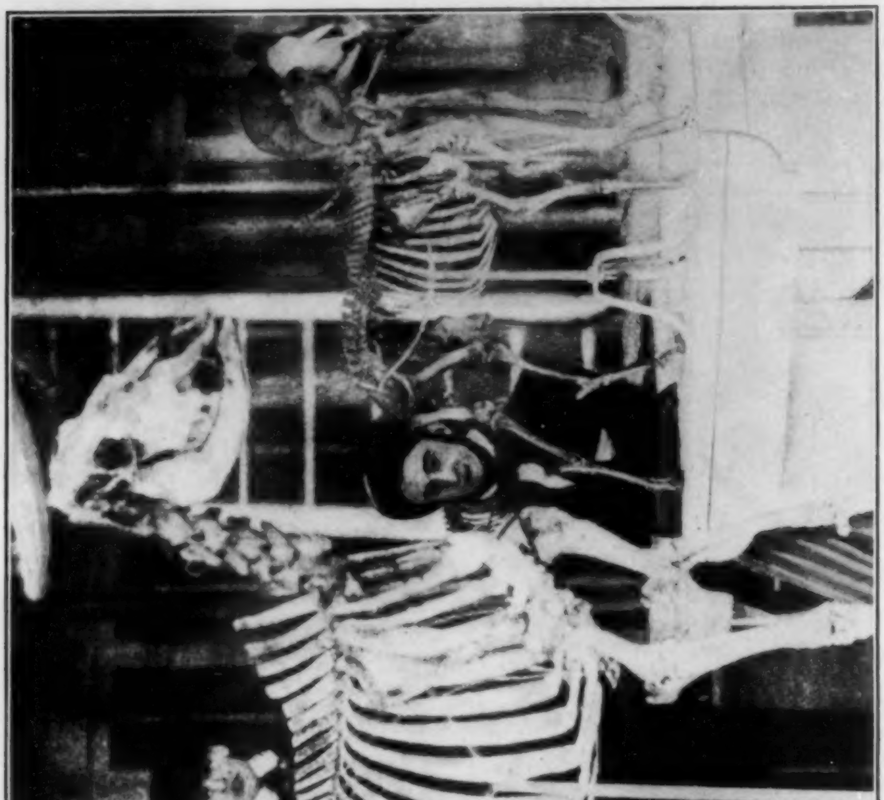
The one hundred and twenty-fifth anniversary of the founding of the Academy of Natural Sciences of Philadelphia—the oldest institution of its kind on this continent—was marked by a series of events and exhibits, the most notable of which was the International Symposium on Early Man and the opening of the Hall of Early Man. Although the symposium was held on the four days preceding, the actual date marking the anniversary of the academy's incorporation was March 21.

Two years ago, the academy, sensing a need to make itself more vital in the life of the community, undertook an Educational Development Program, that has resulted in the formation of a Department of Education and the re-establishment of the Department of Geology and Paleontology. Seventy-five years before, in the pristine glory of Joseph Leidy, Isaac Lea and Edward D. Cope, the academy had been America's center of these studies. After a survey by Dr. Edgar B. Howard, plans were laid to again establish the academy's leadership in geology and paleontology. New space was appropriated to house the study collections of the pioneers; the Carnegie Institution of Washington appointed research associates to work at the academy, and in the Southwest expeditions, under the leadership of Dr. Howard, acting curator of geology and paleontology, discovered important evidence of Early Man's existence in North America.

In November, 1936, it was decided that no more appropriate way of celebrating the one hundred and twenty-fifth anniversary could be pursued than by holding an International Symposium on the subject of Early Man.

Accordingly, Dr. John C. Merriam, president of the Carnegie Institution of Washington, accepted the chairmanship of a committee to form a program. Dr. Edgar B. Howard agreed to act as secretary, and Dr. George Grant MacCurdy, director of the School of Prehistoric Research, Dr. Edwin G. Conklin, executive officer of the American Philosophical Society, and Dr. Hellmut De Terra, research associate of the Carnegie Institution and associate curator of geology and paleontology of the academy, consented to assist them. Invitations were sent to scientists throughout the world to join in the symposium.

In order that the public might better participate and understand the purpose of the symposium and the general subject of Early Man, the academy's exhibits department arranged a Hall of Early Man, wherein the exhibit material brought to the academy might be dis-



MUSEUM OF THE ACADEMY OF NATURAL SCIENCES IN 1838

THE OLD BUILDING AT TWELFTH AND SANSOM STREETS, PHILADELPHIA. THIS IS BELIEVED TO BE THE EARLIEST PHOTOGRAPHIC RECORD OF AN AMERICAN MUSEUM INTERIOR. THE YOUNG MAN IN THE CENTER IS TRADITIONALLY SUPPOSED TO BE JOSEPH LEIDY.

DR. EDGAR B. HOWARD AND JOHN COTTER
INSPECTING THE STONE TOOLS WHICH HAD JUST COME FROM THE SAN DIEGO MUSEUM FOR EXHIBITION IN THE HALL OF EARLY MAN.

played with graphic understandable labels. This hall was opened on March 17, before a large audience of the academy's members and the visiting delegates to the symposium.

As outlined in the preliminary announcement that accompanied the invitations, the purpose of the symposium and its related exhibits was to focus the attention of the scientific and lay world on the advances being made in the study of Early Man. In its final form the program consisted of thirty-three original papers which were read over a period of four days and which were followed each afternoon with round-table conferences on European, Asiatic, North American and African chronology and a discussion on typology and distribution of Folsom and Yuma points.

To the symposium came more than 400 scholars. These included G. H. R. von Koenigswald, of Java; Dorothy A. E. Garrod, of England; Aleš Hrdlička, of the U. S. National Museum; Père Teilhard de Chardin, of China; V. Gordon Childe, of Scotland; Earnest A. Hooton, of Harvard; Josef Kostrozewski, of Poland; Robert Broom, of South Africa, and Kaj Birket-Smith, of Denmark.

In every respect, those attending the symposium might have been described by the very words of the founders themselves, "Gentlemen, Friends of Science and of a rational disposure of their leisure time."

Could any of the founders glimpsed at the opening session on March 17, they would have known that their initial meeting a century and a quarter before had laid a firm foundation.

JOHN H. FULWEILER
THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

THE NATURAL HISTORY EXPEDITION TO SUMATRA

An expedition to collect rare wild animals of Sumatra, Netherlands Indies and the neighboring regions of the Far East and to gather geographic and natural history information and photographs has been sent out under the joint auspices of the National Geographic Society and the Smithsonian Institution.

The party, which is already in the field, is headed by Dr. William M. Mann, director of the National Zoological Park, and the animals which are captured will be added to the collections there. Accompanying Dr. Mann are Mrs. Mann; Dr. Maynard Owen Williams, staff representative of the National Geographic Society; and Malcolm Davis and Roy Jennier, of the National Zoological Park staff.

This expedition is unusual in the fact that it not only will bring back Far Eastern wild animals to the United States, but it also carried a large collection of North American wild animals from the United States to Sumatra. These animals, which are as rare in the Far East as are Far Eastern animals in America, will be presented by Dr. Mann as gifts to zoological parks in cities of Sumatra and elsewhere.

The North American animals include ten alligators, two jaguars, two mountain lions, three opossums, two raccoons, two black bears and five hellbenders, which are a species of large salamander from the Alleghanies. They have the peculiar characteristic of breathing through the skin, having neither lungs nor gills. These animals, taken from surplus collections at the National Zoological Park, were shipped direct from New York to Belawan-Deli, Sumatra, via the Cape of Good Hope, under the care of Mr. Davis and Mr. Jennier.

To feed the animals on the 40-day voyage the National Zoo sent with them 1,000 pounds of frozen beef, 100 pounds of frozen fish, 500 pounds of special bear bread baked in the zoo's own bakery, and a barrel each of apples, sweet potatoes and carrots. Most of the animals had been in the National Zoo almost since birth, so it was expected that confinement on the voyage would be no hardship for them. The two jaguars were born in the zoo 18 months ago.

Dr. and Mrs. Mann and Dr. Williams went to Sumatra by way of Japan, Shanghai, Hong Kong and Singapore, visiting zoological parks en route. The party will spend about four months collecting in Sumatra and other nearby islands. It is equipped with special "mercy traps" and a few small cases in which to carry small, delicate creatures. Heavy traps and cages for the larger jungle beasts will be built in the field.

The region to be visited is at present only poorly represented by animals in the National Zoological Park, Dr. Mann feels. He will confer with game officials and naturalists who are familiar with local conditions and will collect whatever he can of the desired specimens.

Mammals, reptiles, birds and a few fishes will be the primary objects of the collectors, but in spare time Dr. Mann hopes also to collect insects and possibly a few botanical specimens.

After the work is completed in Sumatra, the expedition expects to visit the Netherlands island of Ceram, almost 2,000 miles to the east, and possibly some of the East Indies islands not under Netherlands jurisdiction. It is planned also to touch at Bangkok, Siam. The party will return through the Indian Ocean and the Mediterranean.

M. K.

ENGINEERING PROBLEMS IN FLOOD CONTROL

Floods are caused by high rates of run-off resulting from heavy rainfall, melting snow or a combination of the two. The rate of run-off from a watershed is affected by the amount and intensity of the precipitation, stored water

in the form of snow, temperature, size and shape of watershed, geology and soils, topography, vegetative covering and the degree of saturation of the watershed at the beginning of heavy rainfall or rapid melting of snow.

The influence of each of these various factors upon the rate and volume of flood flow makes a very complex relationship, which varies greatly on different watersheds. In planning flood control improvements the engineer, in cooperation with other specialists concerned in watershed improvement, must evaluate the effects of these factors on the watershed upon which he is working, and determine the amount of run-off that may be expected; how much of it can be conserved and used for municipal water supplies, irrigation, power and other uses; and how much must be disposed of as flood water. Of the factors affecting run-off, only the three last named above can be modified by man: (1) The type of vegetative cover can be controlled; (2) the degree of saturation can be influenced by drainage works; (3) the topography is modified in some degree by erosion and by flood-control works.

Floods can be modified or controlled by (1) channel enlargement or improvement to increase capacity; (2) levees to augment channel capacity; (3) reservoirs to store water until the flood crest has passed; (4) erosion-control works and vegetative cover to retard flow into stream channels.

Reservoirs to be effective must be so located that they will retard sufficient run-off from the area above that to be protected to enable the water channels to carry the remaining flood flow without damage to the protected area. In the past it has been assumed that reservoirs for flood control must be used exclusively for that purpose—that it was not feasible to construct a reservoir for flood control and at the same time use it to store water for irrigation, water power, recreation or other purposes. Now it has become apparent that frequently, especially in connection with larger projects, by careful planning of operation a part of the storage available can safely be used for purposes other than flood control.

Levees are generally used to confine the flood flow in a comparatively narrow floodway through the bottomlands of a stream. On most streams a large increase in capacity can be obtained more cheaply by use of levees than by enlarging or straightening the channel proper.

The improvement and enlargement of stream channels to control floods is usually limited to comparatively small streams or watersheds. The amount of run-off from large watersheds is so great that the cost of constructing channels to carry all flood run-off is prohibitive. Channel improvements are frequently made in connection with the use of reservoirs and levees to reduce the size required for such improvement. Clearing stream banks of obstructions and smoothing them or lining them with concrete reduces the friction of the flowing water and in many instances materially increases channel capacity.

In planning flood control improvements it has been usual to charge the cost of the improvements back to the property protected—where material benefit could be shown—although it was appreciated that there are many less tangible benefits of great value to the community as a whole, such as prevention of the interruption of traffic, interference with business, impairment of public health and other similar benefits. Recently there has been a tendency to give increasing consideration to the indirect benefits and to the equity of distributing the costs of flood control works over wider areas or having part of the cost paid by state or federal governments.

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THE PROJECTED WIND TUNNEL AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE Massachusetts Institute of Technology will shortly start the construction of a high-performance wind tunnel to be dedicated as a memorial to the Wright Brothers. Gifts from persons interested in the advancement of aeronautics have made this possible.

With the increasing speed and size of air craft, our existing wind tunnels have become obsolete. In this country, only the great Langley Memorial Laboratory of the National Advisory Committee for Aeronautics has equipment operating near "full scale" Reynold's Number.

The scale effect in model testing depends on the Reynold's Number, the product of velocity and wing chord divided by kinematic viscosity. The Reynold's Number of airplanes has increased more than 200 per cent. since 1918, and this growth rate may be expected to continue. Model data to be safely extrapolated should be taken for conditions corresponding to a Reynold's Number above 10^6.

The power required to obtain the wind in a tunnel varies as the cube of the velocity, the square of the diameter and as the density. It is, therefore, more economical to obtain high Reynold's Number by increasing density than by increasing speed or size.

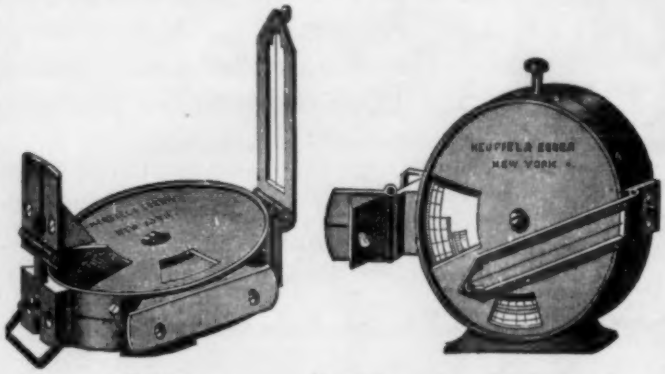
The projected Wright Brothers' wind tunnel will be a closed circuit of welded ship steel with external frames. Pumped up to 4 atmospheres pressure, the Reynold's Number will be about 6×10^6. The throat of the Venturi section will be an ellipse of 10 feet major axis, suitable for models of the order of 7 feet in span. A 2,000 H.P. steam turbine will turn the fan.

The same tunnel when pumped out to 1/4 atmosphere pressure, corresponding to about 35,000 feet altitude, will have a wind velocity of 400 miles per hour. Aerodynamic research at such a speed is considered necessary if future airplanes are to fly in the sub-stratosphere.

The projected tunnel will be unique in that it combines means for operating at a high Reynold's Number to study phenomena of skin friction, turbulence and flow separation, as well as means for the study of high velocity phenomena. It is considered probable that changes in the design of wings must be made when the air speed is such that local velocities approach the velocity of sound.

Due to the use of a variable pressure, access to the model in the tunnel will be extremely inconvenient, and a new type of suspension of the model has been devised, by means of which electrical measuring instruments outside the tunnel will indicate the aerodynamic force of the wind on the model. The principle of these balances is that of the well-known electromagnetic micrometer, by which a very small displacement of an elastic element unbalances the magnetic flux in an air gap, giving rise to unbalance in an A.C. bridge circuit.

J. C. HUNSAKER
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY



as Compass. No. 5400. as Clinometer.